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for June, 1937

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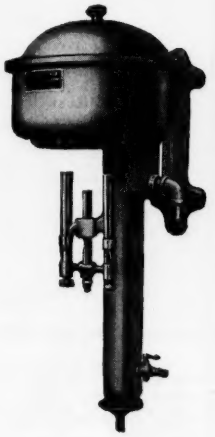

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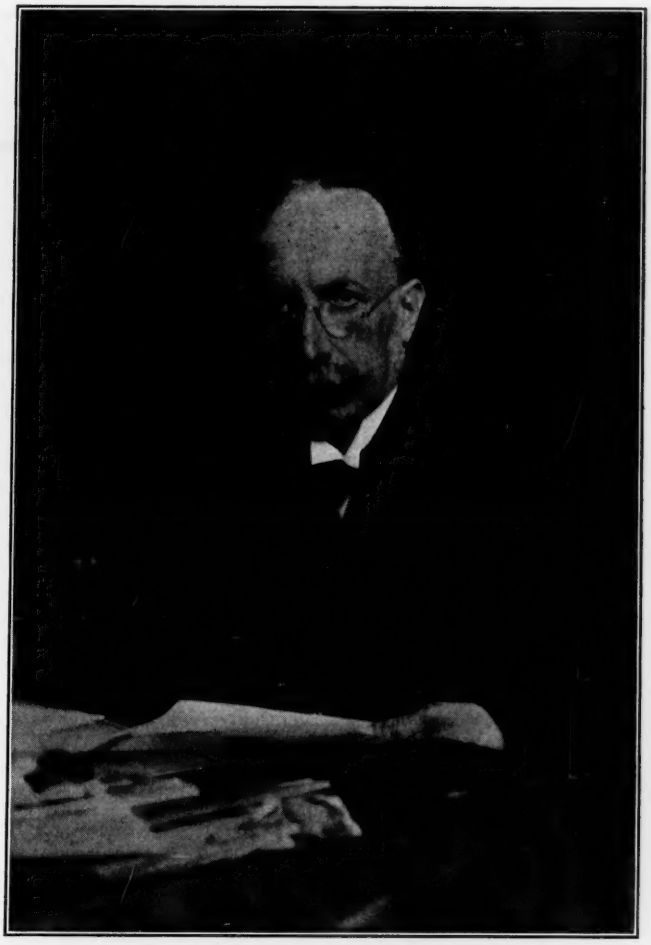

GEORG BREDIG (1868–)

For biographical note contributed by Dr. Ralph E. Oesper, of the University of Cincinnati, see page 284. Dr. Oesper also lent the photograph here reproduced.

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EDITOR'S OUTLOOK

LIFE IS LIKE THAT. So many little girls (both lay and academic) have been writing to the *Times* of late in agitation over the possible non-existence or imminent dissolution of Santa Claus that it becomes a public duty to reveal a few of the more elementary Facts of Life.

Probably fewer than ten per cent. of the graduates of our public schools can either read or write. With due regard for the natural processes of selection, the standard of literacy does not rise remarkably in the output of our high schools, colleges, and graduate schools. What ails education?

My dear little girl, one thing that ails education is that most people have a natural immunity to it. Pasteur encountered the same difficulty in his first attempts to inoculate the common fowl with anthrax. He solved the problem by immersing the unhappy bird in a pail of ice-water and lowering its body temperature. So far we haven't discovered a sure-fire academic equivalent for Pasteur's pail of ice-water. When and if we do, the chances are that the fowl will not submit to the treatment.

Our educational institutions do not prepare students for Life. Embryo engineers are working in filling stations; bachelors of law are selling, or trying to sell, vacuum cleaners; graduates of the schools of journalism are polishing park benches, or leaning on W.P.A. shovels. What ails education?

My dear little girl, you have been reading too many half-baked romances. The palpitant heroine keeps her head under distracting circumstances, and finally leads the handsome, intelligent, athletic, and well-heeled hero to the altar or the justice's desk—here the story ends. But even when all this happens according to schedule in real life, the story does not end at the altar; on the contrary, the really serious complications begin to set in. The matrimonial and the academic grab-bags are alike in that both yield occasional unearned prizes, but for the vast majority of people neither a marriage certificate nor a diploma is equivalent to an unlimited letter of credit or a permanent pass to The Better Things of Life.

For the benefit of all the other little girls to whom we would like to write personally and in detail, we must summarize by saying that education will not make a gentleman out of a louse; it will not make a scholar out of a dullard; it will not make a person of leisure out of anyone who lacked the forethought to inherit an independent income.

To these obvious but too-frequently ignored truisms it is necessary to add that education, like God, can do for you only what you are willing, able, and ready to do for yourself. There should never have been a transitive verb to educate—even in the sense suggested by the original root. Just set that down as a prop to the self-esteem of educators, who often need something to bolster their morale. So if you realize, as you accept your diploma, that "most of it is in the books yet," don't blame education or educators; blame yourself. If you find that, although more or less educated, you are neither handsome, wealthy, nor superlatively bright, don't blame anybody; Life Is Like That.

AMERICA'S PIONEER PRESS AGENT *for* ALUMINUM—J. W. RICHARDS*

R. D. BILLINGER

Lehigh University, Bethlehem, Pennsylvania

AFTER the discovery of an element there is usually a long lapse of time until cheap methods are developed for its commercial production. This country was fortunate in having a chemist and engineer as successful as Charles Martin Hall who advanced the development of the aluminum industry. We were equally fortunate in producing a great advocate and press agent for aluminum in the person of Joseph William Richards.

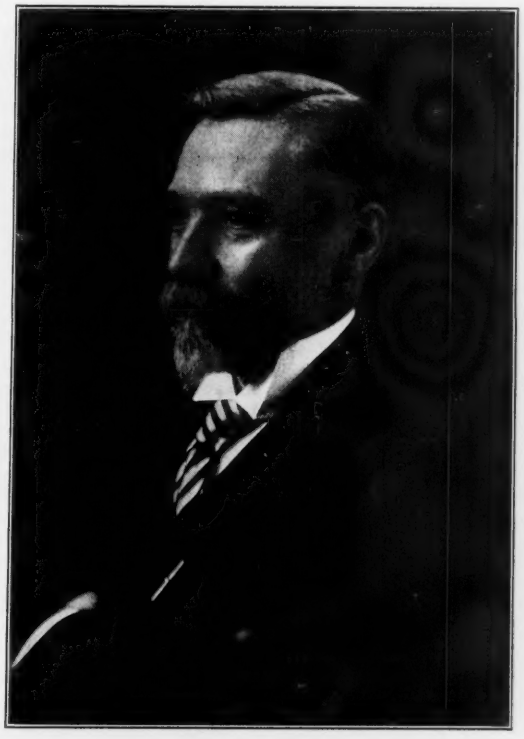
A contemporary of Hall, he became interested in aluminum at about the same time. This year, 1936, marks the fiftieth anniversary of two important events in the history of aluminum. Besides commemorating the invention of the modern electrolytic process of Hall, it is also just fifty years since J. W. Richards wrote the first treatise in the English language on aluminum. It was the subject of his senior thesis when Richards was graduated from Lehigh University in 1886. The following year, 1887, the thesis was published with the consent of his Alma Mater. Its full title was "Aluminium; Its History, Occurrence, Properties, Metallurgy and Applications, Including Its Alloys." It was a 346-page book printed by H. C. Baird and Company of Philadelphia. A second edition in 1890, and a third in 1896 kept the text up to date and reported the progress of the infant industry.

Richards and the Hall brothers became close friends, and they had many conferences. His wide knowledge of the field was extremely helpful to the inventors in their early efforts at commercial production.

Acknowledgment of Richards' zeal is given in a recent book, "The Aluminum Industry" (*1*), written by Edwards, Frary, and Jeffries. "Richards endeavored to collect everything pertaining to aluminum, and to include in his work everything of scientific, practical, or historical value."

This work alone would merit the placing of Richards' name high in the annals of the aluminum industry. But his efforts did not end here. With him aluminium, as he spelled and pronounced it, was a lifelong interest. He preached its advantages and uses before popular and scientific audiences, in the classroom and the parlor. He lectured and wrote about it at home and abroad. A fourth edition of his book was planned by him but never finished.

Richards was born in Oldbury, Worcestershire, England, July 28, 1864, of English-Scotch parents. His grandfather, William Richards, had been a locomotive engineer and bridge builder. He worked with Stevenson in England on the "Lion", one of the earliest steam locomotives. Richards was brought to America when he was seven years old. His father, Joseph Richards,



JOSEPH W. RICHARDS

was a practical metallurgist in Philadelphia and was awarded the John Scott Medal of Franklin Institute for the first successful solder for aluminum.

Undoubtedly, Richard's interest in aluminum was influenced and encouraged by this work of his father. In later life he often referred in his lectures to "my father's furnace."

The boy was educated in the public schools of Philadelphia, and received the A.B. degree from the Central High School in 1882, being first in his class. In the

*Presented before the Division of the History of Chemistry at the Ninety-second meeting of the A. C. S., Pittsburgh, Pennsylvania, September 7, 1936.

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autumn of that year he entered Lehigh University and majored in chemistry under the late Dr. William H. Chandler. Here, as a serious-minded student, he received the title of "Plug", which stuck to him throughout his life. Short of stature, and of meager build, his college year-book tags him as "A hungry, lean-faced man—a mere anatomy."

From members of his class still living we learn that Richards wasted no time in sports or campus activities. His prowess in the classroom and a certain self-assurance which always characterized him gave him dignity and standing with his fellows. A quotation from the Lehigh Epitome of 1886 describes a humorous incident in a class of lithology. Professor, "Mr. Richards, what can you say of luxullianite?" Plug (with his usual assurance), "Why, sir, the Duke of Wellington's aesophogus was made of it."

On University Day, June 24, 1886, J. W. Richards was the first speaker on the program, taking as his subject, "Heroes of Science." From Lehigh Richards went into industry for a year as superintendent of the Delaware Metal Refinery in Philadelphia.

The thesis which he had prepared in his senior year was carefully revised by him and published. That he was justly proud of his work is testified by a letter sent with his presentation copy to Dr. Chandler. There is a copy of the letter in front of "Aluminium" in the Lehigh Collection.

1802 Catharine St.,
Philadelphia, 12/12/86.

Doctor Chandler,

Dear Sir: Let me present my regrets that lack of time and opportunity denies me the pleasure of returning my Thesis in person.

I thank you for the interest you have taken in its completion, and it is a great satisfaction to me to send you a printed volume of which, I am sure, you cannot feel ashamed.

I have endeavored to do my duty as author, the printer, binder and publisher have apparently done theirs, and I confess, myself, that I feel great satisfaction at the result. Please accept the enclosed volume, with my sincere regards, and may I ask that the other be handed to Professor Frazier, to whom I also have the same regrets to present that I cannot give it personally. Desiring the pleasure of a visit to our works if you come to the city, I am

Yours most sincerely
Jos. W. Richards.

The successful reception of the first work of the aggressive young scientist warranted his recall to Lehigh to join the teaching staff as assistant instructor. His teaching was accompanied by study and researches which won him the degree of M.S. in 1891, and Ph.D. in 1893. His first academic degree had been that of A.C. (Analytical Chemist). Richards was the first man to receive the Doctor of Philosophy degree from Lehigh University. His Ph.D. thesis was entitled "A Calorimetric Study of Copper."

Richards' teaching activities were in the fields of metallurgy, mining, and blowpiping. His services were continuous at Lehigh with the exception of a year (1897–98) when he studied in Heidelberg and Freiberg, Germany. His methods were influenced by the guiding hand of his superior, Professor Benjamin W. Frazier, in charge of mineralogy and metallurgy. In 1903 Richards became professor of metallurgy; from then until his death in 1921 he was departmental chairman.

Richards' success as a teacher made him very popular with his students. His manner was dignified and quiet, but likewise positive and impressive. Meticulous in dress, he would stand before his class in frock coat and fresh cravat, his fine gray-white hair and Vandyke neatly trimmed. In a manner which was sometimes humorously egotistical, he would recount to his auditors details of his experiences as expert witness or consulting metallurgist for legal cases. The incident always illustrated his point and never befogged the sense of the lecture. He could stimulate his students to renewed interest, either in intricate calculations, or profound description. He was fond of telling how James Gayley, steel furnace inventor, had told him: "Richards, you do the damned calculations and I'll build the furnaces."

A favorite topic for his lectures was black-body radiation and the reflection of heat from white surfaces. He showed his classes why radiators should be painted black for best efficiency; and he would suggest that blast furnaces be painted white to restrain heat. In summer he generally wore white to keep heat from his person. Rumor had it that he even carried a white umbrella to reflect the sun's rays.

Richards was an ardent champion of the metric system and he actively supported it in public debate.

In religion he was a Unitarian, although he had been raised a Methodist. He liked hymns and knew them well. Richards was a very active supporter of the Bethlehem Bach Choir. His home—for many years situated on the university campus—was a center for religious and philosophical discussion. In later life he collected paintings on his frequent travels.

A very glowing account of Richards' achievements in the university and in the industrial world has been written by one of his most successful students and associates, Dr. W. S. Landis (*2*) of the American Cyanamid Company. He especially notes the international reputation which Richards gained.

Besides his book on "Aluminium," Richards is best known for his "Metallurgical Calculations," Part I of which appeared in 1906. This covered general metallurgy. In 1907 Part II on iron and steel appeared, and in 1908 Part III, treating non-ferrous metals. The combined works appeared in several editions and were translated into five foreign languages.

He was a skilled translator and insisted that his students keep abreast of advances in foreign countries. From the German he translated, "The Electrolysis of Water" (1901), by Viktor Engelhardt, "The Production of Chromium and Its Compounds by the Aid of the Electric Current" (1904), by M. J. L. Le Blanc, "Arrangement of Electrolytic Laboratories" (1905), by Herman Nissenson, and "The Manufacture of Metallic Articles Electrolytically" (1906), by Wilhelm Pfanhauser. He also was interested sufficiently to translate

from the Italian, "The Cementation of Iron and Steel" (1915), by Frederico Giolitti.

Richards wrote widely for scientific journals. From a volume containing fifty reprints in the Richards section of the Lehigh collection (*3*), we note that about one-fifth deal with aluminum or its compounds. Other fields which he investigated and about which he wrote were electrolysis, thermochemistry, vaporization and specific heats of metals, furnace efficiencies, ferro-alloys, and electric power.

Much could be said of Richards' awards and honors, his activities in learned societies and his popular writings. These are a matter of record in standard biographical references (*4*).

His work in connection with the founding of the American Electrochemical Society deserves special mention. In October 19, 1901, an invitation was sent to some thirty scientists and technical men to assist in forming a national electrochemical society. At the inaugural meeting in Philadelphia on April 3, 1902, he was unanimously named its first president. In his inaugural address Richards outlined the reasons for organizing the new group and summarized, "Differentiation and specialization are the watchword, now, of all progress—industrial, scientific, philosophical. . . . Such is the force which has brought into existence the American Electrochemical Society."

At the time of the first meeting three hundred fifty-three members had been enrolled, and twenty papers were read and discussed. The work of arranging meetings and editing papers was largely done by Dr. Richards who acted as Secretary and Editor of the Society's *Transactions* from 1904 to 1921.

Professor Bradley Stoughton, who succeeded Dr. Richards in the chair of metallurgy at Lehigh has written (*5*) of his influence on the aluminum industry, "To develop a great industry by research and application of new knowledge required just that type of keen mind, tireless intellectual activity, and insatiable seeking after detailed facts and fitting them together to build a whole which Joseph W. Richards possessed."

In his lectures on aluminum Richards prophesied the discovery of a process which would use neither sodium nor electricity. It would be a purely metallurgical one, simple, rapid, and cheap, but one through which aluminum might be produced at a cost of from five to ten cents a pound. He hardly looked for this within fifty years, but certainly within the century.

Dr. Richards was an annual contributor to *The Mineral Industry* on the subject of aluminum from 1906 to 1921. In 1915 he paid tribute to his friend C. M. Hall in words which might almost be said of himself, "He died in harness. He had the characteristics of an inventive genius: original and unusual ideas, which he tested out with great perseverance and mechanical skill. . . . Thus will his spirit still continue to guide the industry to greater achievements."

Dr. Richards died suddenly on October 21, 1921. He was survived by a widow and three children, also his mother and two sisters. A vast number of friends in colleges, industries, and scientific circles mourned his loss. His ashes rest in the Chapel on the university campus where he did his life work.

LITERATURE CITED

(1) EDWARDS, J. D., FRARY, F. C., AND JEFFRIES, Z., "The aluminum industry," McGraw-Hill Book Co., New York City, 1930, p. 14.
(2) LANDIS, W. S., "Joseph W. Richards, the teacher—the industry," Memorial Lecture at the Sixty-sixth Convention of the Electrochemical Society, New York City, September 28, 1934.
(3) Lehigh University Library, "Collected pamphlets of J. W. Richards," Vol. L. R. 516 pp.
(4) "Who's Who in America," 1920–21.
(5) STOUGHTON, BRADLEY, "A scholar and aluminum," *Lehigh Leaflets*, No. 2 (Sept., 1923).

The STORY *of* UREASE

JAMES B. SUMNER

Medical College, Cornell University, Ithaca, New York

WHEN I was studying biological chemistry at the Harvard Medical School during the spring of 1912 Professor Lawrence J. Henderson lectured on enzymes. Henderson declared that no enzyme ever would be isolated until some entirely new method for concentrating enzymes could be devised. This was the beginning of my interest in enzymes. Fifteen years later I was to have the good fortune to disprove Professor Henderson's statement. How this came about is described in the following lines.

Something like one hundred or more enzymes occur

in plants, animals, and microörganisms, and urease is one of these. Its action is upon urea, which it decomposes catalytically into ammonium carbonate.* The ammoniacal fermentation of urea by *Micrococcus ureae* and other species of bacteria was known for many years before von Musculus (*1*) showed in 1874 that the active agent was a ferment or an enzyme. He first noted that putrid urine contains little spherical globules of a diameter of 0.0015 mm. Later he claimed that mucus from the bladder acts like the ferment. He tried to purify the ferment and noted that it was easily destroyed by acids.

In 1890 Miquel (*2*) stated that Pasteur and Joubert believed the ferment to arise from *Micrococcus ureae*. Miquel discovered that a great many other microorganisms contain it. Both von Musculus and Miquel devised methods for the quantitative determination of urea through the ability of bacterial urease to change the urea into ammonium carbonate.

In 1914 most biochemists were familiar with the methods of Marshall (*3*) for the estimation of urea in blood and urine, and the modification of Van Slyke and Cullen (*4*). In these methods the urea is changed into ammonium carbonate by means of urease, after which one estimates the ammonia by direct titration or by titration after aëration. Urease was not readily available until after 1909, when Takeuchi and Inone (*5*) discovered soy beans to be a rich source. The impure urease used in the Van Slyke method was obtained by extracting defatted soy meal with water, centrifuging clear, precipitating with excess of acetone, and drying the precipitate in an evacuated desiccator over sulfuric acid. In 1916 Mateer and Marshall (*6*) found that the jackbean, *Canavalia ensiformis*,† contains approximately fifteen times more urease than the soybean. As the result of this discovery biochemists started using the jackbean instead of the soybean as a source of urease.

In the fall of 1917 I became interested in the problem of concentrating and purifying jackbean urease and resolved to isolate the enzyme. At this time I had but little apparatus suitable for the prosecution of research. I had no special research fund but found work with urease to be inexpensive. Later we obtained a centrifuge, an ice chest, and other necessary apparatus. I was first granted research money in 1928, having been urged in 1927 to apply to the Heckscher Committee by Professor Emeritus S. H. Gage.

We used to purchase jackbeans from Mineola, Texas, and grind them in a coffee mill. This was very hard work, and the material was not ground as finely as could be desired. The urease was extracted from the meal with water, salt solutions, dilute glycerine, dilute alkali, etc. It was very difficult to obtain a clear filtrate, since the solutions were viscous and filtered slowly. The best method for filtration was by suction on a Büchner funnel through a thick bed of filter paper pulp.

In the summer of 1918 I discovered that the jackbean contains three globulins (*7*). Two of these, which I named concanavalin A‡ and concanavalin B, crystallize very readily. The third globulin, canavalin,** did not crystallize. Jones and Johns (*8*) had previously investigated the proteins of the jackbean and had stated that one albumin and two globulins were present. Their only evidence for the existence of two globulins was a difference in the sulfur content of the precipitate obtained by half saturation and by complete saturation with ammonium sulfate. Some years later when Osborne got out a new edition of his monograph, "The Vegetable Proteins", I expected that he would change what he had written concerning the work of Jones and Johns on the jackbean globulins and describe my work. He did not do so, and merely referred to my work in the bibliography. I wrote to him about this but never received any reply.

In 1921 I was due to obtain sabbatic leave, as I should have served as Assistant Professor of Biochemistry at Cornell for seven years. I decided to apply for a fellowship from the Commission for Relief in Belgium Educational Foundation, and, if successful, study enzyme chemistry under Professor Jean Effront, known to me as author of several books on enzymes.†††

I was fortunate enough to receive a fellowship, and sailed for France with my family July 14, 1921. We spent the summer at Grenoble, where I studied French conversation and played tennis. In September we started housekeeping in Brussels, having rented a house at 5 rue Newton. I went to call on Professor Effront and told him in French of my desire to isolate urease. He thought this rather foolish and suggested that it would be better to carry out some immunological experiments designed to show whether my crystalline jackbean proteins were really individual compounds. Effront had no real laboratory and did his work in a back room of his house. He told me to go and ask for laboratory space at the University of Brussels Medical School at Parc Léopold. I went there to visit the head of the department of biochemistry, Professor Auguste Slosse, who told me he did not know whether he could offer me a place to work in his laboratory or not. After waiting for more than a week for a decision I gave up the idea of working under Effront and went to work with the pharmacologist,

* Urease really forms ammonium carbamate which then spontaneously decomposes into ammonium carbonate. SUMNER, J. B., HAND, D. B., AND HOLLOWAY, R. G., *J. Biol. Chem.*, **91**, 333 (1931).

† The jackbean is said to grow wild in Central Africa. It has been imported into the Americas and is grown in the West Indies, in our Southern States, and in the Hawaiian Islands. It is said to be used as a fetish by the negroes to protect their crops. Some use is made of it as green fodder, but the mature beans appear to be employed only as a source of urease.

‡ In 1935 we discovered that this globulin is a hemaglutinin, or substance which agglutinates red blood corpuscles. This is the first hemaglutinin to be isolated. SUMNER, J. B. AND HOWELL, S. F., *Science*, **82**, 65 (1935); *J. Bact.*, **32**, 227 (1936).

** We succeeded in crystallizing this globulin in 1935 after first digesting away interfering proteins with trypsin. SUMNER, J. B. AND HOWELL, S. F., *J. Biol. Chem.*, **113**, 607 (1936).

††† These books are: "Les enzymes et leurs applications," **1899**; "Les catalyseurs biochimiques," **1914**; "Biochemical catalysts in life and industry," translated by Prescott, **1917**.

Professor Edgard Zunz, on the purification of fibrinogen and on the action of jackbean phosphatides upon blood coagulation.

In the meantime I had made unsuccessful attempts to obtain jackbeans, since I had foolishly neglected to bring any with me, having thought that these could be obtained in Europe. Professor Slosse sent me out to the suburb, Terveuren, where the Museum of the Belgian Congo is located, as he thought there might be jackbeans on exhibit there. The officials of the Museum said they had no such beans as I described and advised me to go back to Brussels to the Jardin Botannique. The director of the Jardin Botannique knew what jackbeans were and advised me to send a petition to King Albert. The king, he assured me, would arrange to have a squad of negroes pick jackbeans for me in the Belgian Congo, and within a year's time I should have a plentiful supply. That evening I got busy and wrote to G. E. Reeves of Mineola, Texas, and obtained a bushel of jackbeans within a month's time. Some three months later I again visited the Belgian Congo Museum and happened to notice several very large jars containing jackbeans. These had undoubtedly been there all the time.

In the spring of 1922, having published two research (*9*) papers written in French with the aid of Prof. Zunz, I returned with my family to America and eventually again started working on the isolation of urease. At this time Dr. C. V. Noback assisted me; later his place was taken by Dr. V. A. Graham.

I learned that Folin was using 30 per cent. alcohol to extract urease from "Arlco" jackbean meal, and we found that this was a much better solvent than water, since the alcoholic extract contained less protein, although nearly as much urease, and could be filtered very rapidly through ordinary filter paper.

Dr. Noback had read that Frau Schaumanow-Simonowski (*10*) had precipitated pepsin by cooling pepsin solutions to 0°C., and we tried chilling 30 per cent.. alcoholic solutions of urease. When cooled to −5°C. the urease was almost completely precipitated, together with the concanavalin A and concanavalin B. The precipitate, when dissolved in phosphate buffer and centrifuged from the crystals of the globulins which separated, was found to be concentrated over one hundredfold.

We tried adsorption experiments, following the general procedures of Willstätter, using various preparations of aluminum hydroxide, calcium phosphate, kaolin, Lloyd's reagent, and dozens of other substances, but without satisfactory results. We came to the conclusion that adsorption methods were futile when one is trying to isolate an enzyme.

I often became discouraged and abandoned urease work temporarily in order to work on some other problem. In the winter of 1926 I decided that treating urease with chemicals was inadvisable and that the less one did to this very sensitive enzyme the better. On April 26, 1926, I used acetone instead of alcohol to extract urease. I diluted 158 cc. of acetone to 500 cc. with water, stirred this with 100 g. of jackbean meal, poured the material on a filter, and placed the filtering apparatus in our ice chest. The next morning I centrifuged some of the filtrate and looked at the precipitate under the microscope. It appeared to be crystalline. It had extremely high urease activity. I telephoned to my wife that I probably had obtained crystalline urease. That night I slept but little.

I reported my discovery a few weeks later at the meeting of the Society for Experimental Biology and Medicine at Geneva, New York, but purposely did not describe the method of preparing the crystals. One of the members suggested that the reason why I had not described my procedure was probably because I could not repeat it.

I had thought that when the isolation of the first enzyme in crystalline condition was announced any number of persons would claim to have done this already. But nobody said anything either for or against the paper (*11*) published in the *Journal of Biological Chemistry* in August, 1926. Later one or two German authors referred in footnotes to the discovery, saying that Sumner claimed to have isolated urease as a crystalline protein and that this probably was untrue. This attitude was largely, if not entirely, the result of the failure of Willstätter and his students to isolate any enzyme in pure condition and to Willstätter's widely advertised opinion that enzymes were neither protein, carbohydrate, nor, indeed, any of the chemical compounds known to chemists. Willstätter believed that an enzyme exists attached to some unspecific colloidal carrier. This idea in slightly different form had already been advocated by Perrin, Mathews and Glenn, Röhrmann and Schmanine, and Fodor.

In 1927 Professor Willstätter delivered two lectures on enzymes at the Baker Laboratory at Cornell. Professor L. M. Dennis introduced me to Willstätter after he had finished his second lecture. We talked about crystalline urease. He told me that if I digested my enzyme with trypsin the crystalline protein would be digested away, leaving the enzyme unharmed. I told him that I had already done this and had found the crystalline protein to be resistant to digestion. He then said, "Did you employ trypsin according to my procedure?" When I told him I had used Fairchild's trypsin he threw up his arms as if saying, "What is the use of saying any more," then bowed to me, and walked away rapidly.

In 1928 Professor Hans Pringsheim from the University of Berlin was the Baker Non-Resident Lecturer at Cornell. At the end of his introductory lecture Professor Dennis introduced me to him. Professor Pringsheim at once said to me, "I have read your paper." I had written many papers, but knew that he must mean the article Dr. D. B. Hand and I had published in *Naturwissenschaften* after it had been translated into German by Dr. Gerty Cori. "Yes," he said, "I have read about your isolation of urease, which is not true." "But why is it not true?"

I asked him. "Oh," he replied, "I know too little about it to tell you why, but if you will come to Baker Laboratory some time and describe your work on urease before my class then I shall tell you where you are wrong."

So I went to the seminary room of Baker Laboratory some two or three weeks later and delivered a lecture on crystalline urease. Professor Pringsheim asked me a good many questions after I had finished. Finally he said, "Why did you have the presumption to think that you could isolate an enzyme when so many of our great German chemists have failed?" Later he advised me to go to Germany and work on enzymes under Professor E. Waldschmidt-Leitz. I told him that I should prefer not to work under a man younger than myself and under a person who would probably be extremely hostile to my work.

In 1927 von Euler and Brunius (*12*) published an article on urease in the *Biochemische Zeitschrift.* They mentioned that they had been unable to obtain urease crystals by my method. They had then purified urease in several ways, one of which was by adsorption upon aluminum hydroxide at pH 2.7 (which, by the way, is too acid for urease) and had succeeded in concentrating the urease fivefold. Later Jacoby wrote a paper on urease in a German journal (*13*). In this he referred twice to von Euler's inability to repeat my work in a manner that appeared to indicate that he believed von Euler's results rendered my claims exceedingly dubious.

As my sabbatic leave was coming due in 1929 I resolved to go to Sweden to demonstrate to the Swedes how to obtain urease crystals, learn as much about enzymes from von Euler as I could, and have the pleasure of living in a foreign country. But complications now arose. The "Arlco" jackbean I had used in 1926 was rich in urease, containing about one hundred seventy-five units per gram. But in 1928 the amount of urease in the meal had decreased to about ninety units per gram. Using this meal, one could not obtain any urease crystals by my method unless one added acetic acid to the filtrate. Miss Holloway and I got jackbeans from Texas, Honduras, and other places, ground them and analyzed the meal for urease, but the urease content was low (*14*). One sample of beans had much urease but this was not extractable with 30 per cent. alcohol or 31.6 per cent. acetone.

Professor Albert Muller told me that he was to be stationed at Mayaguez, Porto Rico, and he agreed to take back with him about a pint of jackbeans (all we had left) high in urease and to plant them there. About ten months later Muller sent me a big bag of jackbeans which were very rich in urease.* Next we had to consider the problem of getting the beans ground. The Arlington Chemical Company offered to grind them at seventy-five cents a pound, but wrote me that they were not eager to do so since the man who did the grinding always got poisoned from breathing the jackbean dust.

In July, 1929, I sailed for Sweden with a large tin can in my trunk containing about thirty-five pounds of jackbean meal of high urease content. Remembering my experiences in Belgium, I was careful to take with me a stock of test-tubes, Folin-Ostwald pipets, wooden aëration blocks, and aëration apparatus. Later I found that some time would have been saved if I had taken an ice chest, an electric centrifuge, and a colorimeter.

I landed at Göteborg (pronounced "Yeterboy") and then took a train to Stockholm. Dean von Euler told me that his laboratory was being repaired, so I spent a month playing tennis at a seashore resort not far from Stockholm, called Saltsjöbaden. Later I demonstrated to von Euler how to prepare urease crystals and how to recrystallize them. I worked at the laboratory until January first and later published two research papers dealing with crystalline urease, one in collaboration with Professor Karl Myrbäck.

In 1931 my claim of having isolated the first enzyme in crystalline condition was denied by Waldschmidt-Leitz and Steigerwaldt (*15*) of the German University of Prague. They claimed, of course, that the protein crystals were merely the carrier of the enzyme. These authors had got hold of the jackbean meal I had left Myrbäck to give to T. Svedberg and had prepared urease crystals after my procedure. They added trypsin to the solution of this urease and claimed that the trypsin on incubation at 30°C. digested the protein entirely, leaving the urease unharmed. Willstätter at once accepted these results and mentioned in his research publications that crystalline urease had been disproved.

Waldschmidt-Leitz used sulfosalicylic acid to demonstrate that the urease-protein had all been digested by trypsin. He had employed a concentration of only one part of crystalline urease dissolved in sixty-seven thousand parts of water. Now when sulfosalicylic acid is added to this concentration of urease it takes very good eyes to see any precipitate whatsoever. Waldschmidt-Leitz stated that before digestion the urease gave a plain precipitation and that after digestion with trypsin the addition of sulfosalicylic acid gave a hardly perceptible precipitate. In a paper published later (*16*) Kirk and I asked, "If we can hardly see the precipitate that Waldschmidt-Leitz calls a plain precipitate, what is this thing that he calls a hardly perceptible precipitate?" Still worse, we found that the trypsin present in the digest gave such a heavy precipitate with sulfosalicylic acid that nobody in the world could tell anything about the amount of precipitate given by the urease.

Using comparatively large quantities of urease Kirk and I showed that urease protein incubated with trypsin at 37°C. diminished at a very slow rate and that the urease activity decreased at the same rate. We showed that when very small amounts of urease

* Later the beans grown for us at Mayaguez by Prof. Cowles were persistently low in urease, but we were fortunate to obtain beans remarkably rich in urease from C. O. Martin of Waldron, Arkansas.

were digested with trypsin the urease left could be precipitated with antiurease* and the amount of precipitate given corresponded to the amount of urease activity. With antiurease it was found possible to obtain a visible precipitate when one part of urease was present in six hundred thousand parts of water. We showed that urease inactivated by a few seconds' contact with hydrochloric acid and then neutralized gave no precipitate at all with antiurease.

My friend, Dr. Abbe, helped me translate our paper into German. Mrs. Abbe then corrected our German. We mailed our paper to von Euler, who rewrote it as he considered it too aggressive. He then sent it to the editors of the *Zeitschrift für physiologische Chemie*. The latter sent it to Waldschmidt-Leitz, who wrote to the editors that he intended to withhold it from publication until he had written a reply. von Euler, on learning of this, complained to one of the editors, Knoop, who wrote and apologized to me. Our article was soon published. The next issue of the *Zeitschrift* contained Waldschmidt-Leitz' reply (*17*). In it he stated that he did not, as a rule, answer criticisms like ours. He had employed larger amounts of crystalline urease and had incubated these with a purified trypsin. Since in several experiments the urease protein had diminished at a more rapid rate than the urease activity, Waldschmidt-Leitz and Steigerwaldt again claimed that they had furnished proof that the crystalline protein could not be identical with the urease. They declared that our test for crystalline urease, where we had added antiurease and obtained a precipitate, was not a test for the urease protein but only for the urease.

Soon afterward, in collaboration with Kirk and Howell (*18*), I demonstrated that while crystalline urease is very resistant to trypsin, it is rapidly digested by pepsin and by papain-H_2S and that the digestion by pepsin is at the same rate as the inactivation. The experiments were carried out at pH 4.3 and in this vicinity. At pH 4.3 urease is slowly inactivated, since it is unstable at this pH. However, at 48°C. and pH 4.3 we found crystalline urease to be inactivated nineteen times more rapidly in the presence of active pepsin than in the presence of boiled pepsin. Excess of pepsin was observed to digest and to inactivate urease less readily than a moderate amount of pepsin. This is possibly the first time that excess of an enzyme has been shown to be less effective than a moderate amount of enzyme.

Later, Waldschmidt-Leitz, in a survey of the work on enzymes for 1934 (*19*), claimed that our findings with pepsin simply showed that here the breakdown of the colloidal carrier is more complete than is the case with trypsin. Presumably he meant that urease, on being wholly deprived of a carrier to perch on, cannot exist. Since this time the work with crystalline urease has been rather generally accepted.

Nearly four years after the isolation of urease J. H. Northrop of the Rockefeller Institute announced the isolation of crystalline pepsin. Later trypsin and chymotrypsin were crystallized by Northrop and Kunitz. Soon afterward Sherman and his collaborators announced the crystallization of pancreatic amylase; Theorell in Germany crystallized the yellow oxidation enzyme of yeast; and Anson obtained crystals which he believed were identical with the carboxypolypeptidase of the pancreas.

* Antiurease was obtained by injecting urease in gradually increasing doses intraperitoneally into rabbits every five to eight days for thirty days and then every three days for thirty days more. The animals were then sometimes able to tolerate as many as one thousand lethal doses. At this time the rabbits were bled, and the serum was employed as a source of antiurease. Later it was found possible to purify antiurease through precipitation with excess of urease, washing the precipitate with 0.9 per cent. salt solution, decomposing the insoluble urease-antiurease with dilute hydrochloric acid, bringing to the isoelectric point for urease and centrifuging down the denatured urease. Antiurease is the first anti-enzyme to be obtained in highly purified condition, and this is probably the first indubitable proof of the existence of an immune anti-enzyme. KIRK, J. S. AND J. B. SUMNER, *J. Immunol.*, **26**, 495 (1934); *J. Biol. Chem.*, **94**, 21 (1931).

LITERATURE CITED

(1) MUSCULUS, F. VON, *Compt. rend.*, **78**, 132 (1874); **82**, 333 (1876).
(2) MIQUEL, P., *ibid.*, **111**, 397, 501 (1890).
(3) MARSHALL, E. K., JR., *J. Biol. Chem.*, **14**, 283 (1913); **15**, 487, 495 (1913).
(4) VAN SLYKE, D. D. AND G. E. CULLEN, *ibid.*, **19**, 211 (1914).
(5) TAKEUCHI, T. AND R. INONE, *J. Coll. Agr. Imp. Univ. Tokyo*, **1**, i (1909).
(6) MATEER, J. G. AND E. K. MARSHALL, JR., *J. Biol. Chem.*, **25**, 297 (1916).
(7) SUMNER, J. B., *ibid.*, **37**, 137 (1919).
(8) JONES, D. B. AND C. O. JOHNS, *ibid.*, **28**, 67 (1916–17).
(9) SUMNER, J. B., *Compt. rend. soc. biol.*, **86**, 108 (1922); **87**, 388 (1922).
(10) SCHAUMANOW-SIMONOWSKI, E. O., *Arch. exp. Path. Pharmak.*, **33**, 336 (1894).
(11) SUMNER, J. B., *J. Biol. Chem.*, **69**, 435 (1926).
(12) EULER, H. VON AND E. BRUNIUS, *Biochem. Z.*, **183**, 1 (1927).
(13) JACOBY, M., *ibid.*, **198**, 163 (1928).
(14) SUMNER, J. B. AND R. G. HOLLOWAY, *J. Biol. Chem.*, **79**, 489 (1928).
(15) WALDSCHMIDT-LEITZ, E. AND F. STEIGERWALDT, *Z. physiol. Chemie*, **195**, 260 (1931).
(16) SUMNER, J. B. AND J. S. KIRK, *ibid.*, **205**, 219 (1932).
(17) WALDSCHMIDT-LEITZ, E. AND F. STEIGERWALDT, *ibid.*, **206**, 133 (1932).
(18) SUMNER, J. B., J. S. KIRK, AND S. F. HOWELL, *J. Biol. Chem.*, **98**, 543 (1932).
(19) WALDSCHMIDT-LEITZ, E., *Ann. Rev. Biochem.*, **3**, 47 (1934).

I do think that the study of natural science is so glorious a school for the mind that, with the laws impressed on all created things by the Creator, and the wonderful unity and stability of matter and the forces of matter, there cannot be a better school for the education of the mind.—FARADAY

WHAT INDUSTRY WANTS *of* ITS CHEMISTS*

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BEFORE starting on this, I am reminded very much of the experience of McNeill Whistler, the great American artist, who, as you may know, was sent to West Point. He claimed to have left there on account of failure in his chemistry examination. He was asked the question, "What is silicon?" His answer was, "Silicon is a gas." He afterward made the statement that if silicon had been a gas, he might have been one of the greatest military men in the United States, but as silicon was not a gas, he decided to become one of the greatest painters in the United States, all of which was very lucky or unlucky for the country.

As we see it here, after discussing the matter with our Director of Research, Dr. Irving E. Muskat, and our Technical Director, Mr. Dwight Means, colleges and universities should teach chemistry students fundamental scientific principles and sufficient facts to give them a sound working knowledge of the science. They should train students in the experimental approach to a problem, in the methods of scientific thought, and in the interpretation of experimental data. This applies particularly to chemical engineers, who should be taught how to determine the commercial feasibility and the economic soundness of the processes and products to be manufactured. To this end college or university curricula should be so planned that a student, upon completion of his graduate work, should have:

1. a background of general scientific training, with an understanding of the interlocking relationships of the different branches of the sciences and the importance of the scientific method;

2. a specific knowledge of chemistry or chemical engineering;

3. a detailed knowledge of the branch of chemistry which he has chosen for his specialty.

When it comes to the requirements for the successful prosecution of chemical research, this demands imagination, vision, and inventiveness, combined with a sound knowledge of the fundamentals of his science and an ability to draw valid conclusions from experimental data. A chemist with those qualifications has a better-than-average chance for success and would be considered an asset to any industrial laboratory.

The question is, "Where are we going to get such men?" There are available chemists sufficiently well trained to carry out experimental work under close supervision and with detailed instructions, but men of this character have a limited sphere of usefulness and will rarely rise beyond the status of technicians who are used to collect facts for others to interpret. The industrial research laboratories need and seek men who not only can solve the problems arising in plant operations or resulting from sales demands, but who can initiate research investigations to improve the products or processes in use and, further, to develop new products and new uses for the products now manufactured.

It may be argued, with some justice, that the above attributes are a function of *intelligence* rather than *education*, but intelligence is certainly not so rare a quality that the universities can be exonerated of their share of the blame that so few such men are available.

It cannot, in our opinion, be too strongly stated that the primary function of a college or university should be to *teach* its student body. A system under which the prestige of the department is measured solely by the prestige of the individuals of the staff, a system under which advancement in rank for the faculty is determined solely by productivity in research, almost automatically relegates teaching to a position of secondary importance. It is recognized that the faculty should conduct research in order to be able to teach it. The effectiveness of the teaching, however, depends in a large degree upon the attitude of the teachers, and altogether too frequently the professor is inclined to regard his students as so many "laboratory assistants," who will prepare compounds, run analyses, and collect data for him. Students are used by the teachers to do routine work and in turn are rewarded with a graduate degree. Later on these students find that, through no fault of their own, they are too expensively trained for technicians' work and too inadequately trained to do any other. The intelligent graduate may be able to supplement his training through the medium of his own efforts and by experience in a subordinate industrial position, but such supplementary training is often not effective and is, after all, very dearly bought.

The obvious place to obtain fundamental training is the university, and both students and industry suffer when this is not the case.

To summarize we can say:

1. Present graduates are well trained for laboratory assistants.

2. There are few leaders and original thinkers in the

* Contribution to the Symposium on What Industry Wants of Its Chemists, conducted by the Division of Chemical Education at the Ninety-second meeting of the A. C. S., Pittsburgh, Pennsylvania, September 10, 1936.

group; this is the most serious shortcoming of all.

3. They have practically no knowledge of economic values. Depreciation, overhead, operation costs, return on investment, etc., are all matters of another world. The training should relate more to economic phases of industrial chemistry. School problems should contain more dollar marks, ton, and carload figures.

4. Graduates often do not make sufficient effort to cultivate the friendship and help of non-technical men. The most undistinguished operator or foreman will often make valuable observations to a technical man when he is a friend.

5. Many graduates are satisfied with mediocre performance from themselves. They are capable of doing good work, but are not willing to put forth the additional effort that makes the difference between "fair" and "very good." This is partly due to too many "activities" in school which reduce the amount of time available for studies to a point where one devotes a minimum of time and effort to his work.

6. Men are too much inclined to do good work only when their duties are pleasant. They should realize that they have to make good on *every* job before they move to something better.

WHAT *the* CHEMICAL INDUSTRY EXPECTS *of the* COLLEGE*

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THE chemical industry, touching as it does every branch of human activity and of scientific and technical advancement, is an extremely involved and complicated part of our economic life. Its units vary from a small one-man power institution producing one or more specialties, to a highly integrated aggregate producing thousands of different materials finding outlets in scores of directions. The interdependency of the many branches of the industry in the requirements of raw materials, intermediates, and for the profitable disposal of by-products, naturally has directed development toward the complex commercial aggregation. This tendency is not native to any one country or economic system, but is universal, and is probably more highly integrated in several countries in Europe than it is in America.

At this particular season of the year our ears are burdened with the outbursts of the seeker for political office. One of the favored mouth-filling phrases is that of monopoly. It certainly does not apply to the chemical industry, as anyone in the industry who has sat through a meeting of a sales unit quickly learns. Perhaps I should except the almost universal tendency to turn to institutions of learning for our personnel. In this respect our educational plants are gaining a monopolistic grip upon the supply of future operators and executives, for the industry has passed the stage where its staff possesses only haphazard experience.

Our industry is dependent upon the services of a wide variety of trained individuals. The more highly developed units employ civil, mechanical, electrical, mining, metallurgical, and chemical engineers. The physicists and chemists develop, control, and operate our processes, and they have their counterparts in the administrative offices, in medical, legal, statistical, and accountancy experts. We, therefore, must realize that the industrial unit, even though it devotes its entire attention to chemical fields, is not manned solely by chemists, nor should we expect it to be.

I present these brief structural specifications as a starting point for the development of my subject since, without such a background, my thesis would not be intelligible. The particular field that the chemist plays in my organization diagram does not end at the laboratory desk, or, should he be engineer-minded, at the drafting table. His opportunities extend to sales and executive offices—that is, assuming he is prepared for administering such functions. Therefore, it behooves the college to enlarge its scope of training so that its important preparatory course covers a sufficiently broad basis, if these opportunities are to be capitalized by its product.

First of all, therefore, the chemical graduate should be prepared to become part of an organization. The days of the individual, highly specialized, small chemical unit are passing and will be of even less importance in the future. Since he must associate and coöperate with others, personality becomes of extreme moment. From my experience with colleges, personality is left to "grow like Topsy." Unless the student is fortunate enough to be gifted with athletic prowess, team work and coöperation are left entirely to chance. Since the

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colleges seem to find a place in the curriculum for every kind of curious ism that the dictionary catalogs, it seems to me that some serious effort should be made to establish a department responsible for developing the personal aspect of its raw product. I believe the department of psychology should be required to present a sane and sensible program for such a development of personality, habit, coöperation, and contact. Remember that we are dealing with men interested and specializing in science and engineering, and such a course must be direct, brief, and to the point. The capacity to absorb instruction may be assumed to be rather great. Perhaps the greatest obstacle will be the faculty directing such a course and their inability to reduce a scheme of instruction to the terse, practical form that appeals to the scientific-minded individual. If that is the case, then our institutions require some fundamental revision in faculty personnel.

Of further import is the fact that we must teach this raw material that the world expects him to contribute in return for the opportunities it affords him. He must be taught what industry expects of him and that it will reward him only in measure as he delivers. It is not WPA employment. I stated above that there is no monopoly in the chemical industry. In short, what I am telling you now is that industry is highly competitive and it can return only for services rendered. Therefore, it is extremely important that our chemist be taught the source of his pay check and the machinery by which it arrives.

The problem is much broader than merely picturing a few organization diagrams, or a theoretical flow of product to customer. It gets back to the very fundamentals of our economic and national structure. These students, who one of these days will become the leaders of industry, must be trained, not only in the fundamentals of the classic economics but in the relation of those classic principles to national set-up and well-being. They must be taught the fundamental principles of government, the proper relationship of government to industry and to private life.

Many of our institutions of learning have accumulated faculties who mistake liberty for license. Their idea of academic freedom is foreign to the true concept. Usually, the most vociferous of these proponents are shallow-minded individuals lacking either in intellect or in mental activity sufficient to analyze through to a conclusion the many doctrines they so fluently turn loose on the student and the public. I hear them speak of Capitalism, Fascism, and Communism, making firm pronouncements concerning the application of such political theories without the slightest real knowledge of the actual recorded facts. Somehow or other they seem to take their cue from those in high political office where respect for word and truth have completely disappeared. A half story to them is all that they require, be it measured either by completeness or verity. Fortunately, one rarely finds them in the scientific and engineering faculties. I am not narrow-minded, nor am I conservative. It has been my good fortune to have had opportunity to view the practical working of these several forms of government and to have studied them first-hand with adequate equipment for learning the real truth of the details of their functioning. Therefore, it is extremely important that our institutions of learning rid themselves of the lazy and the ignorant on their faculties if we want our chemists to receive just as truthful and honest an education in civics and economics as they get in mathematics and physics. Perhaps it might also be well to instruct our faculty concerning the source of their pay check and income as we have asked above in the case of our future employees.

I believe that industry expects of its chemists ability to read, write, and speak the English language in an intelligible form. An involved and complicated presentation of a scientific subject to me always creates a suspicion of a lack of fundamental knowledge. I do not mean that the chemist must describe one of his processes so that it is thoroughly understandable to the illiterate mountaineer. I do insist that he present his project so that it is intelligible to his associates, most of whom have had the benefit of a higher education, even though not in chemistry.

I believe that a modest amount of modern languages is an asset. We laid a great deal of stress on this some years ago when most of the chemical knowledge was locked up in foreign publications, but today we are making a pretty good job of producing our own literature, and this Society stands at the top of the list in the character and scope of such publications. It has always seemed to me that in view of the fact that most colleges require one or more years of preparation in foreign languages for entrance, any further instruction in such languages should be carried on in the professional course pursued. As for the average scientific and engineering man, I think he would get more out of the foreign language by being required to pursue such language from a text relating to his own chosen profession, and such properly falls into the departmental division of activity. For example, I am certain that a chemist would gain more useful knowledge of a foreign language if forced to read a German text, say, on the history of chemistry than many of the German classics forced upon him by the language department.

And, finally, we come to chemistry itself. I think that our institutions must recognize the complexity of the industry and subdivide their activities along several lines. Very great progress has been made in this direction, although I am not certain that I could agree with all of it. The splitting off of chemical engineering from the purely chemical course was logical, yet I was very much out of patience when I heard one of our great professional societies arguing whether or not a knowledge of chemistry was an essential qualification of a chemical engineer. Fortunately, the chemists won at least half the victory. Just as the metallurgist also split away from the chemical industry, so we will have to make similar further subdivisions. The inorganic and organic chemists will have to diverge earlier and earlier in their training. I really feel organic chemistry is due for an

entire revision in the program of fundamental introduction and instruction. I might say the same of physical and biological chemistry. Such paths of divergence in education will begin at an earlier date in our future college training.

But, after all, we still need what we used to call in my school days the general chemist, that is the man who knows something about atoms and molecules and has a little smattering of qualitative and quantitative analyses and something more of synthetic and manufacturing chemistry. In these complex commercial institutions which I have pictured in my introduction it is these individuals who more and more are going to develop into the executive, managerial, and commercial divisions. We must have them, and our colleges must continue to produce them. Let us not be led too far astray by the physicist and his publicity complex.

Irrespective of these specializations which have been mentioned, industry recognizes that the college cannot produce a research director, a division superintendent, or even a minor executive ready for immediate service. There are in this country some ten thousand individual and independent institutions producing chemicals or using chemical processes. The college cannot be expected to produce even a very small percentage of tailor-made graduates ready to step in and run these institutions. There is a postgraduate period of training through hard work and plant experience which the college graduate must prepare to undertake. The college can merely make that training easier and shorten the necessary period by a thorough grounding in fundamentals, leaving the details to be picked up later. Industry does not expect anything more, and it is prepared to offer sufficient compensation and to create opportunities for this postgraduate period of specific training.

If I might sum up—industry wants the college to furnish it with a rating on personality that is nearly as precise as a rating on mathematics. It expects the college to furnish fundamental instruction in the civic relationship of the individual to the community, the same honesty of treatment to be afforded to that instruction as is demanded in physics or mechanics. It demands that the applicant for employment coming from the college shall be able to read, write, and understand the English language.

It asks for fundamental training, specialized as to subject matter, in the several branches of the chemical science. It has its own requisitions for men from its several divisions, and expects the college to so classify its product so that the specifications, which are not severe by the way, may be applied readily to the several classes of graduate.

In return, the industry has shown a skill and a perception that has enabled it to weather the present business depression to an almost phenomenal degree; therefore, it offers a security higher than that of most other professions. It has maintained employment to a very high degree. Its wage schedule ranks with the best. Its youth presents unlimited opportunities. In short, it is willing and able to pay the bill.

WHAT INDUSTRY WANTS *of* ITS CHEMISTS*

F. W. WILLARD

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WHEN I objected to participation in a symposium on the subject, "What the employer in industry wants in a chemist," your chairman dared me to come here and air my views on the subject of education in chemistry generally.

It is only fair to give the reasons why I refused to discuss the specific subject assigned, by quoting from a paper read before a conference of heads of chemical engineering departments and engineering deans, held at the University of Michigan in 1931.

"What does the chemical industry, or industrial employers, in general, expect of the Chemical Engineer or the engineering graduate in general?

"With due acknowledgment of outstanding exceptions, I suspect that industrial employers in general do not know. If one were to judge by their casual conversations they don't expect much. The ancient and honorable (?) method of trial and error still seems to be the vogue in spite of much heralded methods of selection and training.

"The industrialist employer is at heart a believer in the ruthless screen of experience in the development of his key men. I neither condemn nor defend the process. It *is*. And under the pressure of competition it bids fair to continue as the prevailing custom. But it is wasteful and tragic. Can it be mitigated?

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I do not know, but I would like to leave with you a few suggestions, for though I do not defend industrial methods of recruiting young engineering graduates, I believe that if the waste is to be diminished and the disappointments and disillusionments of the young men mitigated, the job must begin at least at or before matriculation in the professional school.

"I may be wrong, but is seems to me that faculties worry too much about the prospective employer's specifications. At least they seem to seek, in a most humble spirit, advice from the industrial employer on this problem. Generally, in so doing, they are boring a dry hole. Industrial executives are not competent to judge the effectiveness of curricula."

The situation, in my opinion, has not changed. When an employer is looking for a chemist with thorough professional training, he tries to get a National Research Fellow or a man with equivalent postdoctoral training and he may pick a physicist or a biologist and never know the difference.

Chemists, chemical engineers, physicists cannot be produced in the usual four years of undergraduate study except in very narrow specialized lines at the sacrifice of a proper education.

I have no mandate to stand here and try to tell teachers of chemistry how to do their job. No employer is competent to do it.

A certain practical result has accrued from the current method of teaching chemistry under the classical compartmentalized method of teaching the sciences. In a haphazard way the method has produced tangible results, largely, I believe, because the disciplines have been stiff and only the superior individual survived. I have no quarrel with those who adhere to it because it has produced results, but I have the effrontery to come here, without authority, to tell you that you are entering an area of diminishing returns and unless a new concept of education is developed in colleges and higher institutions, they will forfeit the public confidence they now enjoy.

Let it be understood that I do not claim any originality of ideas. A few voices among the teachers of higher institutions have been crying in the wilderness for some years, but inertia, vested interests, and some extreme conservatism in administrative forms builded upon the classical isolation of fields of learning are obstructing the development so sorely needed. I should think that the results of the Pennsylvania Study would jolt administrative officers of colleges and universities. Instead, the buck seems to be passed to the primary and secondary schools.

To some extent, at least, the extremity of specialization is responsible for the complacency of college and university teachers today.

Research is the deity worshiped, and the successful specialist does not generally apply to his problem of teaching the scourge of self-criticism which he applies to his research activities. He is too proud to go to the primary and secondary school teacher and learn from them the proper spirit of humility.

Against the probability that my statements will be received with contempt and ridicule, I still venture to say that the sources of real progress in education today are in the ranks of your humble brothers and sisters who are carrying the terrifying load in primary and secondary schools. I commend to you a searching study of their problems and the methods which they are developing to meet them.

Among their most serious obstacles today is lack of understanding sympathy, yes, even contempt, on the part of their high-brow brothers in the universities.

They are valiantly struggling to prepare their pupils for life in a delicately balanced social order. Fortunately, most of these pupils will not go beyond the primary and secondary schools, but because of limited resources, secondary-school teachers cannot segregate the majority from the minority, and the high-handed arbiters of college entrance requirements dictate the methods whereby the minority must be qualified.

The primary and secondary teachers have, in spite of these handicaps, made good progress in the coördination and integration of subject matter. Mathematics is being coördinated with general science (How many higher institutions do it?), with geography, with commercial studies. Languages, literature, art are being effectively integrated with the social studies. (Within the administrative framework in how many higher institutions is this being done?) They would gladly teach chemistry and physics as one subject of fundamental science integrated with mathematics, and the biological and earth sciences, if you in the higher institutions would abolish your present form of entrance requirements.

To do that you must give more than lip service to the doctrine of the unity of the sciences, and particularly to those classical divisions of physics, chemistry, and mathematics. This requires courage, for your administrative set-up, yes, even your physical plants, are built upon the old creed of isolationism. It will take a deal of jolting. Vested interests on the campus are powerful and will die very hard.

However, it is to be hoped that the rapidly expanding knowledge of nuclear science will blast your old compartment walls to dust.

Though you may now disdain the advice of a lawyer, I believe that you will have to swallow some of President Hutchins' recent advice, however unpalatable it now seems to be.

The Isaiahs in education today are a small handful. They do not seem to be making much headway, but perhaps they have studied the experience of their prototype and know that their mission is only to save the remnant.

You cannot make a chemist in four years and you are foolish to try; but you can, if you will have the courage, give your undergraduates an epistemology of the physical sciences upon which they may build a successful professional career.

WHAT INDUSTRY EXPECTS *of* ITS CHEMISTS*

E. F. DU PONT

E. I. du Pont de Nemours and Company, Wilmington, Delaware

IN COMING before you to discuss the question of "What Industry Expects of Its Chemists," I have the privilege of representing one of the oldest chemical firms in this country and one whose progress through the years has been vitally influenced by chemically trained men. E. I. du Pont de Nemours, who founded the business in 1802, was a chemist, having learned the science by association and study with the old master, Lavoisier. In the present personnel of the du Pont Company, consisting of forty-one thousand employes, there are approximately three thousand people with chemical training. Each year there are employed directly from the technical schools a number of individuals trained in the various branches of chemistry, and we have a reasonable expectation of continuing to do so. I merely cite these facts to show that the du Pont Company, and I believe the chemical industry generally, is vitally interested in the training of its future chemical employes.

The question of "what does industry expect of its chemists?" is one about which much has been written and spoken. However, there are some aspects of the subject, which we, as a good customer of the chemical schools, would like to stress particularly, and these are points which we have observed over a number of years in our relations with the young chemically trained men coming into our Company.

Chemically trained men in the service of the du Pont Company are used not only in research, but in process development, production work, and, in some cases, in sales work, so I shall attempt to cover the subject rather generally, without particular emphasis upon any one line of endeavor.

In approaching this subject, there are certain factors that we must take for granted, for the sake of brevity. We will assume that the courses of instruction to which the young chemists are subjected are essentially the same, as all the well-known technical institutions have good courses in chemistry at the present time. There are also certain other characteristics that we expect in all of our prospective employes, and I will merely enumerate them. Such qualifications as good character, good health, neat appearance, courage, dependability, and industry are expected in an employe in any position from that of office boy to senior executive.

Presupposing a good technical background, one of the most important things is good personal characteristics, or personality. This word personality is a much overworked one, and one that is rather hard to define accurately. To me it does not mean merely that a man has a pleasant smile, a bright manner, and a good handshake, but it goes much deeper than that, it is really the characteristic that enables him to get things done. Note that I say get things done, rather than do things. I make this point deliberately, because in modern business it is not the "lone wolf" who achieves results, but rather a combination of the efforts of a group working together in a coöperative manner under proper direction which achieves the final results. We believe in this principle thoroughly throughout our organization, and our men are carefully picked for their ability to work well in groups with others. Generally speaking, we expect the college-trained men who come with us to develop so that they will be able to hold positions of responsibility. This involves the supervision of others. In order to discharge his responsibilities successfully, the leader must be fair and square in all his dealings and must have a sympathetic attitude toward those for whom he is responsible. He must be well-liked and respected, and the best results will come when his group works for him because they like him, and not because they fear him.

We believe that high scholastic standing is important as an indication of ability to think and to concentrate. Also, we believe that achievements in extracurricular activities are important as an indication of ability to coöperate, and to respect the judgment and direction of others. This combination indicates more than average ability and is a promising background for future performance. I think it is generally conceded that the most successful men are those who have accomplished a balance between classroom and extra-curricular activities, rather than extremists in either line.

Another characteristic which we regard as extremely important is loyalty. It is a very important step that the young graduate takes when he associates himself with a business organization. He should evaluate all the facts that he is able to obtain on the concern which he approaches. This procedure can be compared to that which one follows when investing his money, that is, to be sure that he picks out the best possible situation which will yield him the greatest return for his efforts. By that I do not mean necessarily financial return at the start. That is certainly important, but probably more important is the character of the busi-

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ness management and the opportunity it offers for growth and advancement as effort and ability warrant. Of course, these remarks must be tempered somewhat by the condition of the times when the graduate is seeking employment. As we all know, the past few years have been very trying ones for the young graduate in his endeavor to get a foothold, and difficult ones also for business concerns to retain trained men. Granted, however, that the young graduate has selected the concern he wishes to affiliate himself with and has been successful in obtaining a starting point, he should then give it his loyal support. Considerable public good will can be obtained by the contacts the public has with a concern's employes, and conversely, a great deal of ill will can accrue if the employes are not loyal to their employer.

I come now to the more specific things, which can be improved upon directly by the educational institutions themselves. The first one is the ability of the individual to express himself clearly and concisely in writing. The ability to write a good report is rather essential in young graduates. The composition of a report decides whether the writer or the reader must do the work. If the reader has to do the work in order to get the essentials from a report, the chances are that it will not receive the attention it should, and the report will lose its effectiveness. The essential thing, therefore, in report writing is to draw a conclusion briefly and concisely and to show clearly the reasons for arriving at that conclusion.

The ability to express oneself clearly when addressing a group is also a valuable asset. It is a desirable attribute in any line of work, and the successful man has generally acquired this ability, through force of necessity, by practice and training. Our opinion of the importance of this qualification is evidenced by the fact that we have actually gone to the length of instituting speaking courses for certain of our men who have been out of college for several years. We feel that the colleges and universities can be of material help on this point.

Accuracy is another essential point which we require in our chemically trained men. In any line of business, it is important that when a man makes any statement, either oral or written, that he state the facts as they are. The man who is not sure of the facts when questioned by his superior and merely makes a guess is one who sooner or later will cause the organization a serious loss by making a false statement or giving misleading information. This quality of accuracy can be developed by the proper kind of instruction and leadership during the course of training at the university.

We have noted in certain of the graduates that come to us a tendency to feel that they are thoroughly trained to do anything that is required of them and that their way of doing things is the only way. The most successful man, of course, is the one who is entirely open-minded and willing to learn as much as possible from others as he progresses up the ladder. A technical education can be regarded as a tool in a man's equipment which will help him achieve his ambitions. My thought in this connection can be expressed as follows: that the chemist should have the greatest self-confidence in his own ability, but should have humility as regards his knowledge.

I would like to mention also that we note a lack of economic understanding in its relation to his work on the part of the young graduate. It is generally necessary for industry to train these young men to think in terms of money outgo and income. The young chemist who goes into manufacturing work at the start quickly picks up this quality because of his daily association with profit and loss in the operations. However, the research man is not subjected to this constant pressure and, therefore, does not as quickly acquire this quality of cost-mindedness. It would be of some benefit to industry if this idea could be better instilled in the young men while at college.

We feel that the young graduate should have some understanding of modern industrial organization and the specific opportunities that exist for chemically trained men. I am fully aware of the fact that considerable effort is being devoted now at the colleges and universities to give the students a better appreciation of this question. However, as we view the young men completing their courses each year, there still remains much to be done on this subject. To be more specific on this point, men should know something about the organization of a modern industrial research laboratory and of a modern manufacturing plant. They should know the difference between fundamental and applied research. They should know what development work is and its relation to plant processes. They should know, in a general way, what the chemically trained man going into the production end of the business is required to do, and the things which will enable him to become successful in this line of work in the shortest time. After interviewing a large number of young men, I have the feeling that most students postpone consideration of these practical phases of their education until they are actually confronted with the necessity of finding a job. It would be far better if thinking of the future could be started earlier in the course.

Now that I have brought to your attention the foregoing points, I realize that some constructive suggestions are in order. To effect a better appreciation on the part of the students of the points that have been brought up would, I believe, generally require only a change of emphasis in certain stages of the training now being given, rather than any revamping of existing curricula. For example, practically all chemical courses offer a few electives in the liberal arts field, and it would not be difficult to encourage the technical students to take courses in public speaking or business English.

There is another concrete suggestion which I would like to make at this time; to wit, that it is a commonly accepted fact in the training of men that the tone of the organization is set by the men at the top. It seems to me that this same principle must be true among stu-

dents, as well as men in industry. If this be true, then the closer and more intimate are the relations between student and educator, the better will the young man's character be molded and his ability be directed along the proper channels.

This brings me to my last point, and that is that the men in the chemistry departments of the various institutions are, and can be, of invaluable aid to industry by advising of the characteristics of the young men under their supervision. In a comparatively large industry there are a number of types of occupations, and, as we all know, there are men who are better fitted for certain types of work than for others and it is up to industry in coöperation with the educators to help get the individual in the proper niche where he can do his most effective work.

In conclusion, I would like to sum up briefly characteristics which we expect of the chemical graduate. I am still presupposing that he has been subjected to a good technical course.

1. He must have the proper personal qualifications to enable him to fit into an organization and develop in it.
2. He should have a mental excellence as indicated by class standing and should have broadened himself by extra-curricular activities.
3. He should be loyal to the organization which employs him.
4. He should have ability to speak and write clearly and concisely.
5. He should be accurate.
6. He should have some knowledge of the cost of doing business and his relation to it.
7. He should have an understanding of modern industrial organization and the chemist's relation to it.

If we are on the verge of a cyclical industrial expansion, it becomes increasingly important that we maintain and further develop the fine spirit of coöperation between the colleges and industry, so as to enable young men to be in the best possible position to take their part in this important trend.

WHAT *an* EMPLOYER EXPECTS *of a* CHEMIST*

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EDITOR'S NOTE: *Dr. Whitmore spoke extemporaneously, following a mimeographed outline which was distributed to members of the audience. The outline is reproduced here.*

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THE following staccato analysis of the problem is a summary of the opinion of nearly one hundred research and personnel directors who were consulted as to the qualities which they find most necessary for success in members of their staffs. Although such extraordinary emphasis is put on the qualifications of the *man* as distinct from the *chemist* it should not be imagined that any amount of these personal qualifications will make up for lack of skill and knowledge in chemistry itself. On the other hand, any distinct lack in the necessary personal qualifications will cancel the utmost in skill and knowledge. From the point of view of the trainer of chemists and that of the chemists themselves an encouraging feature is that most of the qualities stressed by the employers are ones which can be developed and improved by conscious thought and effort.

In summary the employer wants:

1. *A good member of his organization* who can live in satisfying relation to (a) his superiors, (b) his equals, (c) those under him, (d) the public, workmen, janitors, non-technical staff, etc.
   Common sense. Decent disposition. Sense of fairness. Play-the-game. Team work. Not humble, not a nuisance.
   Tact. Meet the other fellow more than half-way. Ask for help. Give help. Coöperation. Give credit freely.
   Tactful independence (not a yes-man). Avoid discontent and irritation.
   Golden Rule. See the other fellow's viewpoint, even the Director's—who must make money to maintain the group.
   Health.
2. *Certain spiritual and mental qualities* such as (a) *Honesty* (integrity, self-honesty, scientific honesty, face facts, open-mindedness, independent thinking, critical attitude on data including one's own, impersonal attitude to facts);
   (b) *Loyalty* (self-loyalty, loyalty to ideals and to group, fairness, sincerity, play-the-game);
   (c) *Sense of humor* (sense of proportion, no inferiority or superiority complexes, common sense, judgment);
   (d) *Adaptability* (versatility, shifty attack, quick mental reaction, resourcefulness, common sense, cost sense);
   (e) *Responsibility* (promptness, accuracy, thoroughness, planning);

* Contribution to the Symposium on What Industry Wants of Its Chemists, conducted by the Division of Chemical Education at the Ninety-second meeting of the A. C. S., Pittsburgh, Pennsylvania, September 10, 1936.

(f) *Originality* (initiative, curiosity, why? how? imagination, common sense);
(g) *Controlled optimism*. Diagnosis of problems. Perspective. Tactful courage of convictions. Willingness to discuss ideas. Interest in people and things. Why *can* it be done?
(h) *Neat habits* in work, thought, and dress.
(i) *Recognition* of *profit motive*.
(j) *Accomplishment* (industry, energy, persistence, self-starting, finishing, common sense, driving power, enthusiasm);
Health.

3. *Technical skill* in (a) *Laboratory work* (accuracy, speed, efficiency, neatness, accurate and complete data, accurate interpretation, tackle *big* jobs, not merely the little ones);
(b) *Library work* (cost, accuracy, speed, completeness, patents, blue prints);
(c) *Presentation of material orally and in reports* (receiver's viewpoint, accuracy, clarity, judgment, debating, patents).
Health.

4. *Knowledge*—a considerable amount—well-organized and in readily usable form—correlated facts—not merely facts—not just theories—not bare principles—common sense—accuracy—working knowledge—ever-increasing knowledge—read—discuss—grow—make money.
Health.

A MAN WHO WORKS HARD AND INTELLIGENTLY

A CONSIDERATION *of the* WHAT, *the* WHY, *and the* HOW *in the* TEACHING *of* CHEMISTRY*

ED. F. DEGERING

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THE teaching of any course centers around certain objectives. These may or may not be well defined. They exist, nevertheless, as the ultimate justification for offering the course. In the teaching of chemistry, these objectives may be of two different types. The one is concerned with the presentation of chemistry as a cultural subject, whereas the other aims at the *teaching of chemistry*.

There are many arguments that might be presented in favor of teaching chemistry as a cultural subject to high-school students and to college freshmen. The majority of these students take chemistry because they are the victims of a peculiar set of circumstances. It may be the rigid requirements of the curriculum, the idea of a doting mother, the desire of a fond uncle, or some combination of uncontrollable factors that is responsible for the registration of these students in courses in chemistry. Whatever the contributing causes, there are thousands of students in chemistry courses every year who have no inherent interest in the subject.

It is the presence of this group that brings home to the instructor the obvious conviction that his fundamental objective in presenting the course *might* center around the cultural aspects of the subject. There is strength in mere numbers, and the instructor may be inclined to direct his efforts toward the apparent welfare of the majority. He is apt to devote an unwarranted portion of his time to the mere registrants in his course and to neglect the few who are really interested in chemistry as a science. He is likely to be confronted with a choice of spending the major portion of his time in the interest of those who are never to be associated with the chemical profession, or of inspiring, encouraging, and properly training those who are to become the chemists of tomorrow.

A critical analysis of this general situation leads, it seems, to but one conclusion—the chemistry instructor *should teach chemistry*. If he fails to do this, he sacrifices his opportunities to make indirect contributions toward the progress and ultimate achievements in his chosen profession; for from the students enrolled in the chemistry courses of today, will come the leaders in the chemical profession of tomorrow. Their success or failure will be attributable in no small degree to the type of chemical training they have received. The chemistry instructor plays, in this respect, an important rôle in directing the future of the chemical profession.

In "What's Wrong with Chemical Education?"[1] Taylor voices the opinion that "the most important single factor in turning out high-grade research chemists is expert teaching." The writer interprets this to mean that the chemistry instructor *should teach chemistry*.

* Presented before the Division of Chemical Education at the Ninetieth meeting of the A. C. S., San Francisco, California, August 21, 1935.

[1] TAYLOR, HARDEN F., "What's wrong with chemical education?" J. CHEM. EDUC., **11**, 511 (Sept., 1934).

Some will be concerned with the eighty, ninety, or ninety-five per cent. who may attend their classes as a matter of routine. In shaping one's course to meet the needs of the minority, what is to be said about the supposedly neglected majority? The writer wishes to hazard the inquiry as to whether or not the chemistry instructor, who teaches chemistry, is neglectful of the majority?

Can a student maintain that he is neglected merely because the instructor insists on trying to make him think, reason, and develop his mental facilities? Can a student feel slighted because the instructor compliments him by giving him an opportunity to take part in exercises in mental achievement? Should any effort, *directed* toward the development of a student's mentality, be regarded as mediocre by the teaching profession or its constituency? Is not our entire educational system based upon the assumption that mental development is desirable, beneficial, and profitable from the standpoint of good citizenship? Is not the greatest need of the coming generation men and women who actually think? If so, why should an instructor feel that he is faltering in the discharge of his duties by providing opportunities for mental development?

Let it be assumed, then, that the instructor in chemistry should teach chemistry. He is still faced with the problem of how this is to be accomplished most effectively. How shall he conduct his course so as to offer the maximum opportunities for the acquisition of chemical knowledge, the development of laboratory technic, and the stimulation of original thinking?

In confirmation of such a teaching program, Taylor wrote that "the most valuable...qualification of a research chemist is imaginativeness or inventiveness."[1] Then he raised the question, "Is creative imagination an innate talent or gift possessed by the lucky, and hopelessly beyond the reach of others? Or can it be inculcated in students, or developed in them by a skillful teacher?" With respect to this problem, he believes, "The discovery that the imaginative faculty can be developed in students by skillful teaching would be the most important advance in education in many a day. A dissection of the creative process seems to indicate that creativeness can or ought to be capable of development."[1]

An approach toward the solution of this problem lies in the fact that "ordinary creative imagination in the natural sciences seems to depend on two main essentials, the actual mental possession of a large number of concepts, and the mental habit of trying to fit them together to produce new combinations or ideas."[1] Somewhat contradictory to this is the concept that "modern education consists of knowing where to find things." Obviously, such an idea is not to be taken at face value. One must first know something before he has any reason for knowing where to find something pertaining to it. A graduate in chemistry, who merely knows where to find things, is not prepared for a successful career in the chemical profession, for he does not possess the basic groundwork that gives rise to independent and creative thinking.

One of the instructor's first problems, then, is concerned with the impartation of more factual knowledge. He must place greater emphasis on the essentials and, if need be, expand the content of his course. Both quality and quantity of material should be critically considered.

As a basic aid in the solution of this problem, the instructor may resort to the use of adequate review outlines. Such outlines serve as a guide book to the student who is embarking on his first journey into a maze of chemical information. The student, in the beginning days of his study of chemistry, cannot differentiate between the essentials and the non-essentials. If the best results are to be obtained, he must have adequate guidance.

The instructor, to be sure, normally functions in the capacity of a guide. He blazes a trail, as it were, and then pauses for reflection at the crucial points. The lecture course, however, as frequently conducted, seems to defeat its very objective. While the lecturer is endeavoring to blaze the trail, the student is feverishly occupied with the prodigious task of taking prolific notes, many of which prove to be disconnected, incorrect, and meaningless.

During this pandemonium of note-taking on the part of the student, the instructor laboriously endeavors to build up definite interrelationships and to correlate the new material with information that the student should have already acquired. The net result of the procedure is that all too frequently the student leaves the class room with nothing more than a few unintelligible notes.

It is the writer's conviction that note-taking, as commonly indulged in, should be discouraged. Too many students lose the import of the lecture as a direct result of their attempt to take accurate and intelligible notes. As a result, the lecture period becomes a dull recital, the lecturer becomes a bore, and the subject loses its grip of interest on the student.

The use of adequate review outlines that stress the essentials can well serve as a substitute for a large part of the student's lecture notes. The use of such an outline leaves the student free to concentrate on the content of the lecture. He can devote his energies to an understanding of the interpretations, explanations, associations, and correlations that the instructor endeavors to emphasize. Such a procedure tends to minimize mere memory work and encourages the student to learn by association and correlation.

During the past few years the writer has used this method of instruction and feels that positive results have been obtained. It admits of the acquisition of more factual knowledge on the part of the student for a given expenditure of energy, tends to encourage interest in the subject, makes the student feel that the lecture hour is worth while, and encourages him to build up a basic background of associated and correlated information.

MAINTENANCE *of* CORRECT VALUES *on* LABORATORY WEIGHTS

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NO APOLOGIES are offered for presenting another paper on laboratory weights. As the result of what would seem to be ripe experience, the writer feels that the weight situation today leaves much to be desired. It is a well-known fact that these standards of reference, against which the quantity of various kinds of matter is determined, even though the manufacturer has adjusted them with nicety, and granting that they have been handled with reasonable care, are subject to "change without notice," such changes, which may be either temporary or permanent, giving rise to errors—sometimes negative and sometimes positive. Yet, year after year, chemists (and physicists) continue to use nonchalantly a set of mass standards without question—oftentimes, it is to be feared, under a happy delusion that the several pieces are still accurate.

The weights commonly employed in scientific work—barring, of course, those of peculiar design that are intended for weighing-devices of unusual construction—are of four different kinds: (1) *one-piece* (class *M* of the National Bureau of Standards), (2) *screw-knob* (classes *S* and *S2*, the latter being the so-called *students' weights*), (3) *sheet-metal*,* and (4) *rider;* the last two conform to the specifications for either class *M* or *S* (or even *S2*), depending upon the precision desired. Of these varieties, the first will be discussed further on, the third and fourth would seem to need no special comments, but the second, being liable to alter in mass on account of certain very subtle influences, is deserving of particular attention. Though all weights, no matter of what style, must be expected to undergo a greater or less decrease in value because of unavoidable "wear and tear," the screw-knob type is peculiar in that the pieces are so often found to have suffered a decided acquisition of substance. It is obvious that any attempt at an explanation of such phenomena rests primarily upon a knowledge of just how these weights are constructed. To begin with, the little system is fashioned in two parts: the *body* and the *knob*, or *handle*, and these parts are subsequently joined together. The knob terminates (looking downward) in a threaded stem, which fits into a cylindrical pocket in the main portion of the weight, the pocket in its turn bearing threads to accommodate the stem. It is to be noted, however, that this extension of the knob does not go all the way to the bottom of the cavity, leaving a space, on the contrary, into which the artisan can deposit fragments of material (brass, aluminum, tin, lead, etc.) for the final adjustment of the weight. And since these major parts are ordinarily cut from brass or bronze, the entire exposed surface of the tarnishable alloy is covered with a suitable protective coating: either by plating with one of the more electronegative metals (platinum, gold, chromium, etc.) or by lacquering. Plated weights have not infrequently shown themselves to be hygroscopic, which is due supposedly to a little metallic salt from the bath still lurking underneath the knob; and it appears that this failure to cleanse all parts thoroughly may in time give rise to a permanent gain of mass, a greenish tinge becoming visible in certain cases just at the line of juncture between the handle and the body. Lacquers differ considerably in their properties; some are too absorptive of moisture to be satisfactory, yet sets of lacquered weights are being produced nowadays that can pass a rather rigid humidity test. The filling of two-piece weights has often been observed to undergo oxidation (and perhaps other chemical changes such as hydration, hydrolysis, and the formation of carbonate), to say nothing of the possibility that the incompletely protected internal surfaces (especially if porous) may take on new increments of matter, since it may not be assumed that the screw-knob makes an air-tight fit with its threaded receptacle. In view of these many uncertainties, it is plain that only through well-nigh incessant vigilance can the operator be sure of his weights; hence it is strongly recommended that, apart from an initial calibration, he conscientiously reëxamine his working set as a half-yearly task.

In regard to the valuation of weights, the method of Richards (*6*), though not favored by testing bureaus, has long been popular in academic circles, owing in large measure, doubtless, to its great arithmetical simplicity as compared with the more elaborate schemes. On the other hand, the original procedure of Richards involves a lengthy series of comparisons with no means of verification (except by repetition) at any stage of the work; and it is evident that, if a mistake be made at any point, it will affect the entire sequence of results. For these, and other reasons, the writer has seen fit to modify the process in question in certain important respects.

It is proposed to keep on hand, and to guard with jealous care, six accurately known weights, each piece being decimally related to its neighbors, to be used only as standards from which the values of other weights

* Weights of coiled wire are sometimes substituted for those of sheet metal.

may at any time be deduced. The denominations of the standards are: 100 g., 10 g., 1 g., 0.1 g., 0.01 g., and 0.001 g.; and to these may be added with propriety a 0.005-g. weight, in case one wishes to test the rider for a "short-armed" balance. Needless to say, the material and construction of these reference pieces are all-important matters, the following being an attempt to summarize the accepted criteria. They should be: (1) sufficiently resistant to abrasion, (2) nonmagnetic, (3) not readily acted upon chemically by atmospheric agents—whether normal or abnormal, (4) nonporous, (5) not appreciably hygroscopic, (6) not easily electrified, (7) having a density (except in the case of fractional pieces) as near to 8.4 g./cc. as may be, in order that the conventional "weight in air against brass" may be utilized with the greatest possible satisfaction, and (8) exhibiting design and workmanship that are, practically speaking, beyond criticism. A formidable list of conditions, to be sure; yet it is believed that they can all be met by the "double-plated" one-piece weights which were put on the market but a few years ago. These standards of mass are machined from homogeneous bronze, the bronze is plated with gold, and the gold, in turn, is covered with platinum. As to the fractionals, they are best made from sheet platinum on account of its extraordinary durability—even down to, and including, the smallest weight. The larger pieces (one gram and upward) should be tested and certified by the Bureau of Standards under class *M;* while the smaller weights, if entire sets are to be calibrated subsequently with an analytical balance—there being no assay or microchemical balance available—may be certified under class *S* (see Table 1), for the precision of corrections, and not the tolerance, differs for the two classes.

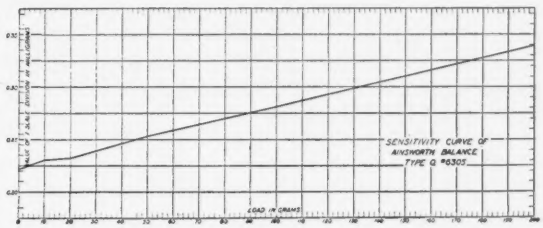
TABLE 1

CERTIFIED VALUES OF STANDARDS

Bureau of Standards Test No.	*Date of certificate*	*Designation, g.*	*Apparent mass vs. brass* *Total value, g.*	*Correction, mg.*	*True mass* *Correction, mg.*	*B. S. class*
69011	March 8, 1933	(100)	99.999,6	−0.4	−0.6	*M*
		(10)	10.000,15	+0.15	+0.14	
		(1)	1.000,02	+0.02	+0.02	
18880	March 17, 1916	(0.1)	0.100,00	0.00	−0.01	*S*
		(0.01)	0.009,99	−0.01	−0.01	
		(0.001)	0.000,99	−0.01	−0.01	

Having thus procured the required standards, the weights of a set under test are divided into groups of four or five each, and the groups are dealt with separately after the manner of Richards until a series of relative values is obtained; whereupon these numbers are recalculated so as to give a new assemblage of values, which last are in terms of the standards of the United States—or, ultimately, the International Prototype Kilogram.

In performing the experiments recorded under Groups I, II, III, and IV, an analytical balance of the finer sort, equipped with a portable magnetic damper, was employed. The sensitivity of the instrument was taken for various loads, using a small weight* to produce the desired displacement, and the results were plotted in the form of a graph (which see).



Starting with Group I, the ten-gram standard (designated 10' g.) was placed upon the *left-hand* scale-pan and was balanced by a crude weight of the same denomination on the *right-hand* pan. Moreover, a small weight (0.005 g.) was laid beside the standard piece, and toward the edge of the pan, in order that the rider might assume a position near to the middle of its path. Then, as the result of trial, shifting the rider back and forth as indicated, the needle was made to remain at the midway (or zero) graduation mark on the index plate, allowing at least one minute for all movement to cease. The standard was replaced by the 10′-g. weight, and, after releasing, the location of the rest point was observed, the change in the position of equilibrium being proportional to the difference in mass between the two weights. The standard was then put back, in place of the first weight to be tested, and the rest point was again taken; and, if the third observation agreed with the first, it was concluded that the condition of the balance had remained constant; otherwise, the comparison was begun anew.† Similarly, the 10″-g. weight was tried against the same standard, the 20-g. weight against the standard and the 10′ g., and so on until all of the pieces under test (amounting to ninety grams), together with the 10-g. standard, had been compared with the 100'-g. weight (the final standard for the group).

Having obtained the rest-point displacements, and knowing the sensitivity of the balance for any particular load, the differences in mass can be readily calculated, and from these a set of preliminary values is derived by simple addition or subtraction‡ on the temporary assumption that this initial standard (10' g.) is perfect, and a value for the 100'-g. weight (to be subsequently made the final standard) will thus have been computed in terms of it (namely, 99.998,0 g.). The corresponding aliquot part of this number is compared with each of the preliminary values, and the differences,

* The little weight was of platinum and had been certified by the Bureau of Standards to represent its nominal value (0.002,00 g.).

† Inequality of temperature is probably the commonest and the most insidious foe to refined weighing.

‡ It is important to avoid any mental confusion as to the sign of the correction. When the weighings are made in the manner described above, a displacement to the right means that the weight (or combination of weights) is heavier than the preceding, and *vice versa*.

COMPARISON OF WEIGHTS (B. S. 18880) WITH STANDARDS (B. S. 69011)

GROUP I

Left pan, g.	*Rest point,* sc. div.	*Change of rest point times sensitivity,* g.	*Preliminary values (actual),* g.	*Aliquot parts of* **99.998,0** *(ideal),* g.	*Corrections. Actual minus ideal,* g.	*Values in terms of U. S. standards,* g.
(10^a)	0.0		10.000,00	9.999,8	+0.000,20	*10.000,15*
($10'$)	−0.6	−0.000,14	9.999,86	9.999,8	+0.000,06	10.000,0
($10''$)	−0.7	−0.000,16	9.999,84	9.999,8	+0.000,04	10.000,0
(10^a) + ($10'$)	0.0					
(20)	−0.9	−0.000,21	19.999,65	19.999,6	+0.000,05	20.000,0
(10^a) — (20)	0.0					
(50)	−0.5	−0.000,13	49.999,22	49.999,0	+0.000,22	50.000,0
(10^a) — (50)	0.0					
(100^a)	−2.1	−0.000,59	**99.998,0**	**99.998,0**	0.000,00	*99.999,6*

25th January, 1936.

COMPARISON OF WEIGHTS (B. S. 18880) WITH STANDARDS (B. S. 69011)

GROUP II

Left pan, g.	*Rest point,* sc. div.	*Change of rest point times sensitivity,* g.	*Preliminary values (actual),* g.	*Aliquot parts of* **9.999,96** *(ideal),* g.	*Corrections. Actual minus ideal,* g.	*Values in terms of U. S. standards,* g.
(1^a)	0.0		1.000,00	1.000,00	0.000,00	*1.000,02*
($1'$)	0.0	0.000,00	1.000,00	1.000,00	0.000,00	1.000,0
($1''$)	0.0	0.000,00	1.000,00	1.000,00	0.000,00	1.000,0
($1^{a'}$)	0.0	0.000,00	1.000,00	1.000,00	0.000,00	1.000,0
(1^a) + ($1'$)	0.0					
(2)	−0.1	−0.000,02	1.999,98	1.999,99	−0.000.01	2.000,0
(1^a) — (2)	0.0					
(5)	−0.3	−0.000,07	4.999,91	4.999,98	−0.000,07	5.000,0
(1^a) — (5)	0.0					
(10^a)	+0.3	+0.000,07	**9.999,96**	**9.999,96**	0.000,00	*10.000,15*

10th February, 1936.

COMPARISON OF WEIGHTS (B. S. 67004) WITH STANDARDS (B. S. 18880 AND 69011)

GROUP III

Left pan, g.	*Rest point,* sc. div.	*Change of rest point times sensitivity,* g.	*Preliminary values (actual),* g.	*Aliquot parts of* **0.999,88** *(ideal),* g.	*Corrections. Actual minus ideal,* g.	*Values in terms of U. S. standards,* g.
(0.1^a)	0.0		0.100,00	0.099,99	+0.000,01	*0.100,00*
($0.1'$)	−0.1	−0.000,02	0.099,98	0.099,99	−0.000,01	0.100,0
($0.1''$)	0.0	0.000,00	0.100,00	0.099,99	+0.000,01	0.100,0
(0.1^a) + ($0.1'$)	0.0					
(0.2)	−0.2	−0.000,04	0.199,94	0.199,98	−0.000,04	0.199,95
(0.1^a) — (0.2)	0.0					
(0.5)	0.0	0.000,00	0.499,92	0.499,94	−0.000,02	0.500,0
(0.1^a) — (0.5)	0.0					
(1^a)	+0.2	+0.000,04	**0.999,88**	**0.999,88**	0.000.00	*1.000,02*

15th February, 1936

COMPARISON OF WEIGHTS (B. S. 67004) WITH STANDARDS (B. S. 18880)

GROUP IV

Left pan, g.	*Rest point,* sc. div.	*Change of rest point times sensitivity,* g.	*Preliminary values (actual),* g.	*Aliquot parts of* **0.100,06** *(ideal),* g.	*Corrections. Actual minus ideal,* g.	*Values in terms of U. S. standards,* g.
(0.01^a)	0.0		0.010,00	0.010,01	−0.000,01	*0.009,99*
($0.01'$)	−0.1	−0.000,02	0.009,98	0.010,01	−0.000,03	0.009,95
($0.01''$)	+0.1	+0.000,02	0.010,02	0.010,01	+0.000,01	0.010,0
(0.01^a) + ($0.01'$)	0.0					
(0.02)	+0.1	+0.000,02	0.020,00	0.020,01	−0.000,01	0.020,0
(0.01^a) — (0.02)	0.0					
(0.05)	+0.1	+0.000,02	0.050,02	0.050,03	−0.000,01	0.050,0
(0.01^a) — (0.05)	0.0					
(0.1^a)	+0.2	+0.000,04	**0.100,06**	**0.100,06**	0.000,00	*0.100,00*

19th February, 1936.

to which the proper algebraic sign must be affixed, constitute the corrections to the several weights on the supposition that the 100°-g. piece represents *exactly one hundred grams*. But the actual magnitude of this weight with reference to the United States standards is *99.999,6* g. (apparent mass *versus* brass), or its correction is −0.000,4 g.; hence by subtracting suitable fractional parts of 0.000,4 from the corrections in the sixth column, the errors (or values) for the weights under examination are eventually obtained in terms of Government standards.

It is scarcely necessary to remark that the remaining groups can be treated in an analogous way, and that the corrected values of the weights in a box can be used in any combination whatever; since, in the final reckoning, they are all on the same basis. No attempt was made to test pieces of denominations lower than one centigram (0.01 g.), for it is generally more convenient to use the rider than to manipulate tiny weights; although, if so desired, the 0.001-g. standard will serve as a starter for a fifth group, comprising the smallest weights in the set—as well as for taking the sensitivity of the balance.

The weights experimented with under Groups I and II were screw-knob pieces of lacquered brass (incidentally, of Dutch manufacture) which were tested by the Bureau of Standards approximately twenty years ago; they had been used only occasionally and then usually

as bases of comparison for other weights. In nearly every instance the result got by the procedure herein advocated, after rounding off, is in agreement with the certified value (*cf.* Table 2). In other words, it is highly gratifying to see that these two-piece weights have remained constant (or very nearly so) over so protracted a period of time. The sheet-metal fractionals examined under Groups III and IV were of either tantalum or aluminum (two centigrams and downward) and bore a Government test of much more recent date. Here again, a satisfactory concordance between the values found and those on the Bureau's report is to be noted.

TABLE 2

CERTIFIED, OR REPORTED, VALUES OF WEIGHTS TESTED

Bureau of Standards Test No.	*Date of certificate or report*	*Designation,* g.	*Apparent mass vs. brass Total value,* g.	*Correction,* mg.	*True mass Correction,* mg.
18880	March 17, 1916	(50)	50.000,1	+0.1	+0.1
		(20)	20.000,0	0.0	0.0
		(10′)	10.000,0	0.0	0.0
		(10″)	10.000,0	0.0	0.0
		(5)	5.000,0	0.0	0.0
		(2)	2.000,0	0.0	0.0
		(1′)	1.000,0	0.0	0.0
		(1″)	1.000,0	0.0	0.0
		(1‴)	1.000,0	0.0	0.0
67004	April 27, 1932	(0.5)	0.499,98	−0.02	−0.05
		(0.2)	0.199,96	−0.04	−0.05
		(0.1′)	0.099,99	−0.01	−0.02
		(0.1″)	0.100,01	+0.01	0.00
		(0.05)	0.050,01	+0.01	+0.01
		(0.02)	0.020,00	0.00	+0.01
		(0.01′)	0.009,96	−0.04	−0.03
		(0.01″)	0.010,01	+0.01	+0.01

The following advantages are claimed for the present method of calibration: (1) the conversion of a long process into a series of short exercises not only gives mental relief to the operator but it also favors those especially who are subject to frequent interruption, as Hopkins, Zinn, and Rogers (*13*) have pointed out; (2) there is much less danger of results getting "out of alignment" when relatively few comparisons are considered at a time, and, if a mistake is suspected, the work of any one group can be repeated with no great expenditure of time and labor; (3) the use of a preliminary standard of definitely known value, though seemingly superfluous, furnishes valuable evidence as to the reliability of the work in any particular group, seeing that the computed value for this weight should be very near to the certified value;* (4) while a "relative" calibration is adequate for the purposes of analytical chemistry, "absolute" values are necessary for certain physical investigations, and, at all events, the results against legally authorized standards can be in nowise objectionable.

In conclusion, the writer wishes to express his indebtedness with all possible sincerity to the following gentlemen for their unselfish coöperation: Dr. Francis D. Murnaghan, of the Johns Hopkins University, who made a critical examination of Richards' method from a mathematical standpoint and pronounced it altogether rigorous [*cf.* Semon (*17*) and Eaton (*36*)]; Mr. Arthur T. Pienkowsky, of the National Bureau of Standards, who from time to time gave invaluable advice and contributed directly toward the preparation of the somewhat extensive bibliography hereto appended through the loan of his card index on balances and weights; Dr. Reuben Roseman, of Baltimore City College, who verified all calculations and tabulations and, in a series of friendly conferences, offered a number of constructive suggestions.

* The respective quantities found, certified values being given in parentheses, are: 10.000,16 g. (*10.000,15* g.); 1.000,015 g. (*1.000,02* g.); 0.100,01 g. (*0.100,00* g.); 0.009,99 g. (*0.009,99* g.). Despite these excellent agreements, the results (which see) were rounded off, to avoid claiming too much for the work.

BIBLIOGRAPHY

(1) MILLER, W. H., "On the construction of the new imperial standard pound, and its copies of platinum; and on the comparison of the imperial standard pound with the kilogramme des archives," *Trans. Roy. Soc.* (London), **146,** 753–946 (1856).

(2) KOHLRAUSCH, F., Table of corrections for a set of weights, "An introduction to physical measurements" (translated from the 2nd German ed. by T. H. Waller and H. R. Proctor), D. Appleton and Company, New York City, **1886,** pp. 32–5.

(3) WEINSTEIN, B., Ueber Gewicht (Massen-) sätze und deren Untersuchung, "Handbuch der Physikalischen Maassbestimmungen," Julius Springer, Berlin, Vol. II, **1888,** p. 328 et seq.

(4) HAYFORD, J. F., "On the least square adjustment of weighings," Report of the Superintendent of the U. S. Coast and Geodetic Survey, Part II, Appendix No. 10, pp. 515–27 (June 30, 1892).

(5) CROOKES, W., On the correct adjustment of chemical weights, "Select methods in chemical analysis," Longmans, Green and Company, New York City, 3rd ed., **1894,** pp. 679–85.

(6) RICHARDS, T. W., "Note on a method of standardizing weights," *J. Am. Chem. Soc.*, **22,** 144–9 (1900).

(7) MORSE, H. N., Correction of weights: comparison of the different pieces of a set with each other, "Exercises in quantitative chemistry," Ginn & Company, Boston, **1905,** pp. 26–9.

(8) BENOIT, J.-R., "L'étalonnage des séries de poids," *Travaux et mémoires du Bureau International des Poids et Mesures,* **13,** 47 pp. (1907).

(9) MELLOR, J. W., Correcting the weights, "A treatise on quantitative inorganic analysis," Charles Griffin and Company, Limited, London, **1913,** pp. 16–21.

(10) RAE, W. N. AND REILLY, J., "Precision in chemical weighing," *Chem. News,* **114,** 187–9, 200–3 (1916).

(11) GUYE, PH.-A. AND MOLES, E., "Actions of the surface; sources of error in weighings," *J. chim. phys.*, **15,** 360–404, 405–32 (1917).

(12) ANON., "Design and test of standards of mass," *Bur. Standards, Circ. No.* **3,** 89 pp. (1918).

(13) HOPKINS, A. J., ZINN, J. B., AND ROGERS, H., "The standardization of weights," *J. Am. Chem. Soc.*, **42,** 2528–31 (1920).

(14) VOGELENZAN, E. H., "The accuracy of weighings made with varnished weights," *Chem. Weekblad,* **17,** 453 (1920).

(15) ANON., "Magnetic weights," *J. Wash. Acad. Sci.*, **11,** 476 (1921).

(16) MANLEY, J. J., "The protection of brass weights," *Phil. Mag.*, **44,** 948–50 (1922).

(17) SEMON, W. L., "The standardization of weights by Richards' method," J. CHEM. EDUC., **2,** 132–6 (1925).

(18) HARVEY, N. K., "Simple method for standardizing balance weights," *Chem. Eng. Mining Rev.*, **17,** 205–6 (1925).

(19) OSTWALD, W. AND LUTHER, R., Korrektionstabelle eines Gewichtssatzes, "Hand- und Hilfsbuch zur Ausführung

physikochemischer Messungen," Akademische Verlagsgesellschaft m. b. H., Leipzig, 4th ed., **1925,** pp. 82–6.
(20) PIENKOWSKY, A. T., "Short tests for sets of laboratory weights," *Bur. Standards, Sci. Paper No.* **527,** 65–93 (1926).
(21) PIENKOWSKY, A. T., "Testing standards of mass (office standards and test weights)," *Bur. Standards, Miscellaneous Pub. No.* **74,** 103–15 (1926); *Monthly Rev., official publication of Incorporated Society of Inspectors of Weights and Measures* (Birmingham, England), **35,** 157 (June, 1927).
(22) PIENKOWSKY, A. T., "Weights and weighing," International Critical Tables, McGraw-Hill Book Company, Inc., New York City, Vol. I, **1926,** pp. 73–80.
(23) ANON., "Effect of changes in humidity on laboratory weights," *Bur. Standards, Tech. News Bull. No.* **115,** 3–4 (Nov., 1926).
(24) ANON., "Maintenance of national physical laboratory standards of mass," *Nat. Phys. Lab., Rept. for* **1925,** 145 (1926).
(25) ANON., "Stabilization of gold-plated weights," *Bur. Standards, Tech. News Bull. No.* **119,** 5 (Mar., 1927).
(26) ANON., "Changes in weights with changes in humidity," *Bur. Standards, Tech. News Bull. No.* **121,** 4–5 (May, 1927).
(27) PIENKOWSKY, A. T. AND FOWLE, E. S., "Variation of gold-plated screw-knob weights with atmospheric humidity," *Phys. Rev.*, (2), **29,** 910 (1927).
(28) SIERTSEMA, L. H., "Variability of old standard kilograms," *Physica,* **8,** 37–43 (1928).
(29) ANON., "Lacquers for weights," *Bur. Standards, Tech. News Bull. No.* **138,** 142 (Oct., 1928).
(30) ANON., "Chromium-plated laboratory weights," *Bur. Standards, Tech. News Bull. No.* **143,** 23 (Mar., 1929).
(31) ANON., "Some old weights still vary with changes in humidity," *Bur. Standards, Tech. News Bull. No.* **145,** 38 (May, 1929).
(32) WEATHERILL, P. F., "The standardization of weights," *J. Am. Chem. Soc.,* **52,** 1938 (1930).
(33) ANON., "Maintenance of standards: standards of mass," *Nat. Phys. Lab., Rept. for* **1929,** 182 (1930).
(34) ANON., "Platinum plating for repaired weights," *Bur. Standards, Tech. News Bull. No.* **158,** 58–9 (June, 1930).
(35) FELGENTRAEGER, W., "Set of weights for the microchemical balance," *Z. anal. Chem.,* **83,** 422–8 (1931).
(36) EATON, F. C., "The standardization of weights," *J. Am. Chem. Soc.,* **54,** 3261–3 (1932).
(37) ANON., "Calibration of volumetric glassware and analytical weights," *Paper Trade J.,* **94,** No. 21, 25–6 (1932).
(38) FELGENTRAEGER, W., Gewichte, "Feine Waagen Wägungen und Gewichte," Julius Springer, Berlin, 2nd ed., **1932,** pp. 271–94.
(39) ANON., "Nickel-chromium alloys for weights," *Bur. Standards, Tech. News Bull. No.* **186,** 98–9 (Oct., 1932).
(40) SARTORIUS, F., "New division of weights," *Z. anal. Chem.,* **91,** 344–6 (1933).
(41) MANLEY, J. J., "Precision weights," *Phil. Mag.,* **16,** 489–504 (1933).
(42) ANON., "Magnetic damping for laboratory balances," *Bur. Standards, Tech. News Bull. No.* **189,** 1–2 (Jan., 1933).
(43) MOYER, H. V. AND WINTER, P. K., "Comparison of constancy of gold- and chromium-plated analytical weights," *Ind. Eng. Chem.,* **26,** 238 (1934).
(44) DEDE, L., "Standard and precision weights of molybdenum-chromium-nickel alloy," Heraeus Vacuumschmelze 10th Anniv. Vol., **1933,** 81–3.
(45) ANON., "Dealers' stocks of certified 'analytical' weights," *Bur. Standards, Tech. News Bull. No.* **211,** 107 (Nov., 1934).
(46) MANLEY, J. J., "Devices for insuring constancy in the mass of precision weights," *Phil. Mag.,* **19,** 243–51 (1935).
(47) TREADWELL, F. P., Calibration of a set of weights, "Analytical chemistry" (translated by W. T. Hall), John Wiley & Sons, Inc., New York City, Vol. II, 8th ed., **1935,** pp. 15–20.
(48) FINDLAY, A., Calibration of weights, "Practical physical chemistry," Longmans, Green and Company, New York City, 6th ed., **1935,** pp. 15–9.
(49) KOLTHOFF, I. M. AND SANDELL, E. B., Balance, weights, and weighing, "Textbook of quantitative inorganic analysis," The Macmillan Company, New York City, **1936,** pp. 183–221.

DEMONSTRATION EXPERIMENTS USING UNIVERSAL INDICATORS*

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INTRODUCTION

DEMONSTRATION experiments which are simple are more effective than those which involve complicated set-ups and elaborate technic. While the latter may give exact data, the refinements are wasted if the audience cannot interpret the results with ease. This is particularly true in experiments involving changes of hydrogen-ion concentration. When the phenomenon of hydrolysis is demonstrated, the observer may have difficulty in interpreting the many separate color changes met with in covering a wide pH range. This is, of course, due only to the lack of familiarity of the spectators with the indicators used, but rarely are demonstrations carried out with audiences having the necessary experience. A univer-

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sal indicator, on the other hand, has the advantage that only one indicator solution (and one set of color standards) is needed. After the significance of the color changes has been explained, the audience has little difficulty in following and interpreting the phenomena observed.

Many of the universal indicators on the market are not satisfactory for demonstration experiments, because changes in pH do not cause color changes which are systematic, and very often the colors are muddy and not easily distinguished at the distances contended with in lecture halls. Barnstoff (*1*) has described some experiments in which he uses the British Drug House universal indicator which seems well suited for lecture work. American concerns selling indicator solutions now list indicators similar to the B. D. H. product. These indicators have the advantage of a systematic shift in colors from red to violet, following the order of the visible spectrum, and the colors are transparent and brilliant.

Recently, recipes for preparing universal indicator solutions of the type mentioned have appeared in the literature. Since they are not readily accessible, two are quoted here. Van Urk (*2*) describes one which is somewhat similar in behavior to that sold under the B. D. H. trademark:

MATERIALS FOR VAN URK INDICATOR

Tropeolin OO	70 mg.	Naphtholphthalein	500 mg.
Methyl orange	100 mg.	Cresolphthalein	400 mg.
Methyl red	80 mg.	Phenolphthalein	500 mg.
Bromothymol blue	400 mg.	Alizarine yellow R	150 mg.

The dyes are dissolved in 200 ml. of 70 per cent. ethyl alcohol, and one drop in 10 ml. of the solution to be tested is recommended.

Yamada (*3*) has patented the recipe for a universal indicator solution which is even more satisfactory for demonstration purposes, since, as Table 1 shows, the seven spectral colors fall exactly on even pH units over the middle range of the scale.

MATERIALS FOR YAMADA'S INDICATOR

Thymol blue	5.0 mg.	Bromothymol blue	60 mg.
Methyl red	12.5 mg.	Phenolphthalein	100 mg.

The dyes are dissolved in 100 ml. of 95 per cent. alcohol, neutralized (to green) with 0.05 *M* NaOH solution in water, and made up to 200 ml. with water.

Table 1 shows the colors of these two indicators in solutions of decreasing hydrogen-ion concentration.

We have checked the colors of these indicators at the hydrogen-ion concentrations listed, and have found them to be readily distinguishable. With Van Urk's indicator, it is preferable to use standards, but Yamada's colors are recognized without question by the audience. The checks were made electrometrically with quinhydrone against a calomel electrode, except on the strongly alkaline side, and with the Wulff gelatine strip colorimeter over most of the range of the indicator. In case of the alkaline solutions, the colors were checked by use of standard NaOH-H_3BO_3-KCl buffer solutions.

The experiments which follow (including in part some of those cited by Barnstoff) indicate the use to which a universal indicator may be put in elementary demonstrations.

EXPERIMENT I

pH of Solutions of Salts.—A set of color standards is desirable. One may be constructed using some readily prepared buffer mixtures (see Experiment III below),

TABLE 1

pH	*Color of Van Urk's Indicator*	*Color of Yamada's Indicator*
2	orange-red	—
3	red-orange	—
4	orange	red
5	yellow-orange	orange
6	orange-yellow	yellow
6.5	yellow	—
7	green-yellow	green
8	green	blue
8.5	blue-green	—
9	green-blue	indigo
9.5	violet-blue to blue-violet	—
10	violet	violet (purple)
11	violet to violet-red	—
12	violet-red	—

with a known concentration of the indicator, in well-stoppered flasks, or sealed in large test tubes. With Yamada's indicator a concentration of 1 ml. of indicator solution to 10 ml. of electrolyte solution is satisfactory for lecture demonstration purposes, if the mixtures are illuminated by diffused lights from behind. The standards and solutions should, of course, contain the same concentration of indicator. If the solutions are contained in 500-ml. Erlenmeyer flasks, however, a depth of color which is comparable to that of the standards sealed in six-inch test tubes is obtained when only 6 ml. of indicator solution are used in 250 ml. of solution.

Table 2 lists the pH of solutions of several substances, covering the range of the indicators.

TABLE 2

Formula of Electrolyte	*Concentration, Moles per Liter*	*pH*	*Color of Yamada's Indicator*
HCl	0.1	1.0	red
H_3PO_4	0.1	1.5	red
$HC_2H_3O_2$	0.1	2.9	red
H_2CO_3	0.1	3.8	red
NaH_2PO_4	1.0	4.0	red
NH_4Cl	2.0	4.0	red
NH_4Cl	0.1	5.0	orange
H_3BO_3	0.1	5.2	orange
$Zn(C_2H_3O_2)_2$	1.0	6.0	yellow
$MgSO_4$	0.1	6.0	yellow
$NH_4C_2H_3O_2$	1.0	7.0	green
NaCl	1.0	7.0	green
$NaHCO_3$	0.1	8.4	blue-indigo
Na_2HPO_4	0.1	9.0	indigo
$Na_2B_4O_7$	0.1	9.2	indigo
$NaC_2H_3O_2$	1.0	9.6	indigo-purple
Na_2SO_3	1.0	9.7	indigo-purple
NH_4OH	0.1	11.3	purple
KCN	1.0	11.6	purple
Na_2CO_3	0.1	11.6	purple
NaOH	0.1	13.1	purple
Na_3PO_4	1.0	13.8	purple
NaOH	1.0	13.9	purple

EXPERIMENT II

Common Ion Effect.—The change in the pH of solutions of weak acids on the addition of normal salts

of the acid is ordinarily demonstrated using methyl orange with solutions which are acidic and phenolphthalein with alkaline solutions. By means of a universal indicator the entire range may be covered with only one indicator solution, and the extent to which the pH of the solution is altered is more clearly brought out. The colors given by treating 100 ml. of solution with varying quantities of suitable salts are given in Table 3. (The pH values were judged by means of the indicator.)

TABLE 3

Solution Contains (Moles per Liter)	*Substance Added (Moles per Liter)*	*Grams Added to 100 ml. of Solution*	*pH*	*Color Given by Yamada's Indicator*
0.5 *M* $HC_2H_3O_2$	——	——	2.5	red
	1 *M* $NaC_2H_3O_2$	8.2	4.7	orange-red
	1.5 *M*	12.3	5.0	orange
	2.5 *M*	20.5	5.6	yellow-orange
	6.0 *M*	49.2	6.0	yellow
0.1 *M* $HC_2H_3O_2$	——	——	2.8	red
	0.5 $NaC_2H_3O_2$	4.1	5.0	orange
	2.5 *M*	20.5	6.0	yellow
0.5 *M* NH_4OH	——	——	11.5	purple
	1.5 *M* NH_4CL	2.7	—	purple
	2.5 *M*	8.1	9.7	indigo-purple
	3.5 *M*	13.5	9.0	indigo
	3.5 *M*	18.9	8.5	blue-indigo
	6.5 *M*	36.1	8.0	blue

EXPERIMENT III

Phosphate Buffer Mixtures.—The behavior of the three phosphates, Na_3PO_4, Na_2HPO_4, and NaH_2PO_4, can be used to illustrate in a striking manner the usefulness of the modern theory of acids and bases (*4*). When they are dissolved in water, in the presence of Yamada's indicator, the color of the solutions are purple, blue, and red, respectively, showing the approximate pH immediately. Elementary classes readily grasp the significance of the observation if the equilibria are represented by the equation

$$PO_4^{---} + H_2O \rightleftharpoons HPO_4^{--} + OH^- \text{ (to a large extent)}$$

$$HPO_4^{--} + H_2O \rightleftharpoons H_2PO_4^- + OH^- \text{ (to a small extent)}$$

$$H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{--} + H_3O^+ \text{ (to a large extent)}$$

Prideaux (*5*) cites a useful table for the preparation of phosphate buffer mixtures, covering the middle range of Yamada's indicator.

ml. 0.1 *M* NaH_2PO_4	10	8	6	4	2	0
ml. 0.1 *M* Na_2HPO_4	0	2	4	6	8	10
pH	4.0	6.0	6.5	6.75	7.2	9.0 (?)

EXPERIMENT IV

Change in pH on Dilution of a Strong Acid.—If 0.01 *N* hydrochloric acid solution is diluted in steps of ten (use boiled or CO_2 free distilled H_2O) the correct pH is shown by the universal indicator for 0.01 *N*, 0.001 *N*, 0.0001 *N*, and 0.00001 *N* solutions. Equal volumes of the diluted solutions are treated with the same amount of indicator. Van Urk's indicator covers a wider range and is more suitable for this experiment.

EXPERIMENT V

A Non-Instantaneous Reaction.—At present there are few effective demonstrations of the fact that many reactions occurring in aqueous solutions are not instantaneous. The following modification of Nernst's experiment (*6*), with the introduction of a universal indicator, is eminently satisfactory for this purpose. The demonstration is effective even in a large auditorium if suitable illumination is employed.

In a 750-ml. Erlenmeyer flask, 500 ml. of H_2O and 5 ml. of Yamada's indicator are treated with 10 ml. of saturated $Ba(OH)_2$ solution. This causes a brilliant purple color to appear. Five ml. of methyl formate, $HCOOCH_3$ (preferably, but not necessarily, freshly distilled), are added, with swirling of the contents of the flask. A rapid change in color takes place: from purple through indigo, blue, and green (two or three seconds); and a slower change to yellow (one-half hour); orange (one hour); and finally to red (a day), due to the hydrolysis of the ester. For demonstration purposes, it is effective to add more $Ba(OH)_2$ solution after the reaction has proceeded for ten minutes. Various brilliant color combinations appear in rapid succession as the flask is swirled. The explanation of the mechanism of the reaction may be given, but it is not necessary to do so; it is obvious to all, without further details, that the reaction is proceeding at a measurable rate and not instantaneously.

EXPERIMENT VI

Changes in pH at Electrodes during Electrolysis.—Sodium sulfate solution, with universal indicator added in sufficient quantity to give a deep, green color, is used to fill the Hoffman type of electrolysis apparatus. Shortly after the current is turned on, the solution in the tube where the oxygen collects (the anode compartment) becomes red, due to the accumulation of hydrogen ions; the solution in the other arm where the hydrogen collects (the cathode compartment) becomes first blue and then purple due to the accumulation of hydroxyl ions.

By connecting an ammeter in series with the electrolysis apparatus, quantitative calculations based on the volumes of the gases and the number of coulombs of electricity are possible. If 30 or 40 ml. of hydrogen are collected, Faraday's constant may be calculated fairly accurately.

LITERATURE CITED

(1) BARNSTOFF, *Z. physik. chem. Unterricht*, **44**, 255 (1931); *cf.* J. CHEM. EDUC., **9**, 565 (1932).
(2) VAN URK, *Pharm. Weekblad*, **66**, 157 (1929) (through *Chem. Abstr.*, **23**, 752 (1929)).
(3) YAMADA, Jap. Pat. 99,664, Feb. 21, 1933 (through *Chem. Abstr.*, **28**, 2258 (1934)).
(4) KILPATRICK, "Acids, bases, and salts," J. CHEM. EDUC., **12**, 109 (1935). A short résumé.
(5) PRIDEAUX, "Theory and use of indicators," D. Van Nostrand Co., New York City, **1917**, p. 202.
(6) PARTINGTON, "Textbook of inorganic chemistry," 4th ed., The Macmillan Co., **1933**, p. 326, experiment 9.

The FORMULATION *of* PRUSSIAN BLUE

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The several blue precipitates obtained from simple iron ions and the complex iron cyanides may be formulated as derivatives of a polynuclear complex composed of ferric and ferrocyanide ions, the formation of which involves coördination by both ends of the cyanide ion.

✦ ✦ ✦ ✦ ✦ ✦

IN a previous paper it was shown that equimolecular quantities of ferric and ferrocyanide ions, or of ferrous and ferricyanide ions, react instantaneously to form an equilibrium mixture of all four ions according to the equation $Fe^{+++} + [Fe(CN)_6]^{\equiv} \rightleftharpoons Fe^{++} + [Fe(CN)_6]^{\equiv}$; and that the formation of a blue product is subsequent to the establishment of this equilibrium.[1] It is the object of the present paper to answer such questions as, what ions are involved in the formation of the blue product? How does the composition of Prussian blue vary when excess of ferric or of ferrous ions are employed? To what may the common blue color of these products be ascribed?

SOLUBLE PRUSSIAN BLUE

Analysis of the blue product obtained from equimolecular quantities of ferric and ferrocyanide ions, or from ferrous and ferricyanide ions, indicates that it contains one alkali metal ion, one iron ion, and one complex hexacyanide ion; that it is either $KFe^{+++}[Fe(CN)_6]^{\equiv}$ or $KFe^{++}[Fe(CN)_6]^{\equiv}$. Several methods have been employed to distinguish between these formulas. The first which comes to mind is decomposition. Thus sodium hydroxide converts soluble Prussian blue to ferric hydroxide and sodium ferrocyanide. Such evidence of the ferrocyanide nature of the iron blue is invalid, however, because of the operation of the mobile redox equilibrium given above. According to the solubility or complexity of a decomposition product containing one or the other ions, it should be possible to drive this oxidation-reduction reaction to completion in either direction. How this actually occurs and leads to conflicting testimony is illustrated by the claim of Woringer[2] that ferricyanide ion is common to the Prussian blues, since their decomposition with ammonium carbonate yields ammonium ferricyanide.

Other writers have attempted to arrive at the composition of soluble Prussian blue by considering the methods by which it may be produced. Hofmann[3] and his coworkers concluded that it was a ferrocyanide because it was produced from ferric ferricyanide by the action of hydrogen peroxide which is known to reduce ferricyanide, but not ferric ion. On the other hand, Eibner and Gerstacker[4] considered Prussian blue a ferricyanide since it was formed from ferric ferricyanide by the action of sulfur dioxide which reduces ferric ion, but not ferricyanide. Like the arguments based on decomposition, these results are invalidated by the existence of the redox equilibrium.[5]

It is now possible to offer support for the ferrocyanide nature of soluble Prussian blue, which, since it is based upon the redox equilibrium, avoids the objection mentioned above. Since the formation of soluble Prussian blue is relatively slow, some light may be thrown on the question of its composition by noting the effect of excess of each of the ions involved in the redox equilibrium upon the time required for blue formation. As has been demonstrated previously,[1] excess of ferrocyanide, ferricyanide, or of ferrous ions each accelerate blue formation, while *excess of ferric ion actually retards it*—the Prussian blue paradox. While the interpretation of the accelerating effect of the first-mentioned ions is not free from ambiguity the inhibiting effect of ferric ion is illuminating, for the only ionic factor which is *decreased* by excess of ferric ion is *ferrocyanide ion*. This inverse correlation between excess of ferric ion and the rate of formation of Prussian blue leads to the unavoidable conclusion that Prussian blue is derived from ferrocyanide ion.

Other less direct forms of argument may be applied to this problem. Ferric salts are generally found to be less soluble than the corresponding ferrous salts. Similarly, ferrocyanides are generally less soluble than the corresponding ferricyanides. Hence, of the four possible ionic combinations (ferrous ferrocyanide, ferric ferricyanide, ferrous ferricyanide, and ferric ferrocyanide), ferrous ferricyanide should be expected to be the most soluble salt and ferric ferrocyanide the least soluble. Consequently, Prussian blue, which is practically insoluble in water (the term "soluble Prussian blue" is a misnomer connoting the ease with

[1] D. DAVIDSON, J. CHEM. EDUC., **14**, 238 (1937).
[2] P. WORINGER, *J. prakt. Chem.*, (2), **89**, 51 (1914).
[3] K. A. HOFMANN, O. HEINE, AND F. HÖCHTLEIN, *Ann.*, **337**, 1 (1904); K. A. HOFMANN, H. ARNOLDI, AND H. HIENDLMAIER, *ibid.*, **352**, 54 (1907).
[4] A. EIBNER AND L. GERSTACKER, *Chem.-Ztg.*, **37**, 137, 178, 195 (1913).
[5] E. MÜLLER, *ibid.*, **38**, 281, 328 (1914).

which this substance forms colloidal solutions), must be ferric ferrocyanide rather than ferrous ferricyanide. If oxidation-reduction did not intervene, ferrous ferricyanide would be more soluble than ferric ferricyanide which is so excessively soluble in water as to be practically unknown in the solid state.[6]

Further evidence in favor of considering soluble Prussian blue a ferrocyanide may be derived from Kolthoff's work[7] on the precipitation of heavy metals by ferrocyanide and by ferricyanide. Whereas the ferrocyanides of silver, copper, and zinc, for example, showed a marked tendency to form double salts with potassium ferrocyanide, the corresponding ferricyanides were obtained only as *simple* salts. Furthermore, the colors of these *ferricyanides* all corresponded to the colors of the component ions in contrast to the marked difference between the color of Prussian blue and the ions giving rise to it.

PRUSSIAN BLUE AS A POLYNUCLEAR COMPLEX

The foregoing discussion makes it reasonable to consider soluble Prussian blue as potassium ferric ferrocyanide, $KFe^{+++}[Fe(CN)_6]^{\equiv}$. But how does it happen that such a deep blue salt is formed from practically colorless ions? The answer—complex formation—readily suggests itself. Unfortunately, reliable methods of studying complexes (such as conductivity, solubility, and potentiometry) are limited to soluble substances.[8] X-ray analysis may be of some value in studying the complexity of solids, but its failure in the simpler case of silver cyanide vs. silver argenticyanide makes its utility here dubious.[9] With iron salts, magnetic susceptibilities may be indicative of complex formation. Davidson and Welo,[10] however, were unable to demonstrate the existence of a polynuclear complex in Prussian blue by this method. Their failure should not be interpreted as evidence against such a structure since, for example, the behavior of $(FeF_6)^{\equiv}$ which shows a Weiss magneton number of 29 is inconsistent with its formal similarity to $[Fe(CN)_6]^{\equiv}$ which exhibits a magneton number of 12.[11] Lacking more reliable methods of confirming the complex indicated by the color of Prussian blue, recourse will be had in the sequel to an argument based on the *composition* of the several iron cyanide blues. This will be prefaced by a theoretical analysis of the possibilities for supercomplex formation from ferrocyanide ion.

The electronic structure of cyanide ion may be written as :C:::N:, :C::N::, or ::C:N::.[12] In all of these formulas at least one lone pair of electrons is present on both the carbon and nitrogen atoms. In the formation of ferrocyanide from ferrous ion and six cyanide groups, it appears to be the lone pair of the carbon atom which is involved in the coördination bond. This is supported by the fact that alkylation of ferrocyanide yields an isonitrile complex, whereas the alkylation of uncoördinated cyanides (sodium cyanide) yields mainly nitrile. It is conceivable, therefore, that a lone pair remaining on the nitrogen atoms of these cyanide groups may function to coordinate metals; in other words, that a ferrocyanide ion may satisfy *six* coördination positions of simple metallic ions. It should be borne in mind that ferrocyanide ion is an exceedingly stable structure which shows practically no tendency to dissociate into simpler ions.

Hence, ferric ion with a coördination number of six may be coördinated by a ferrocyanide ion thus $[[Fe(CN)_6]^{\equiv}Fe]$. It is evident that spatial limitations prevent one ferric ion from being coördinated with *one* ferrocyanide ion by six bonds. Current stereochemical conceptions of complex salts would limit the number of such bonds to three. Structures should, therefore, be considered in which a ferric ion is coördinated with one ferrocyanide ion by one, two, or three bonds, the six bonds being obtained by involving six, three, or two ferrocyanide ions, respectively. These cases will be discussed in turn.

(*a*) *Three-bond coördination* (*fused 6-rings*).—If three of the cyanide groups of one ferrocyanide ion serve to occupy three coördination positions of a single ferric ion there results the incomplete structure

This unit, containing a system of fused six-membered rings, has three unsatisfied coördination positions on the ferric ion and three uncoördinated nitrogen atoms. While steric limitations prevent the completion of coördination within this unit, inter-unit coördination may occur by a head-to-tail union of these groups. This process resembles the polymerization of unsaturated organic compounds, such as vinyl chloride, for example.[13] Thus, a linear polymer,

may be formed in which successive iron atoms are distinguished not only by their charges but also by the type of coördination bond (C—Fe or N–Fe).

[6] H. REIHLEN AND U. V. KUMMER, *Ann.*, **469**, 43 (1929) claim, however, to have prepared an insoluble isomer of ferric ferricyanide.

[7] I. M. KOLTHOFF, *Z. anal. Chem.*, **62**, 209 (1923).

[8] WM. THOMAS, "Complex salts," Blackie and Son Ltd., London, **1924**, Chap. II.

[9] L. P. HAMMETT, "Solutions of electrolytes," 2nd edition, McGraw-Hill Book Company, New York City, **1936**, p. 120. A preliminary report of the X-ray analysis of Prussian blue has recently appeared [J. F. KEGGIN AND F. D. MILES, *Nature*, **137**, 577 (1936)].

[10] D. DAVIDSON AND L. A. WELO, *J. Phys. Chem.*, **32**, 1191 (1928).

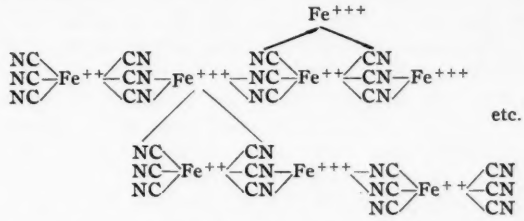
[11] O. BAUDISCH AND L. A. WELO, *Chem. Reviews*, **15**, 11 (1934).

[12] W. M. LATIMER AND J. H. HILDEBRAND, "Reference book of inorganic chemistry," The Macmillan Company, New York City, **1929**, p. 227.

[13] W. H. CAROTHERS, *Chem. Reviews*, **8**, 353 (1931).

(*b*) *Two-bond coördination* (*6-membered rings*).—Should only two of the cyanide groups of a single ferrocyanide ion be considered to be coördinated by a single ferric ion there would be obtained the unit

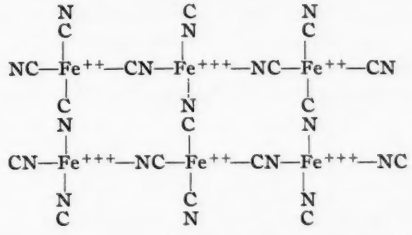
which contains a six-membered ring and four vacant positions on the ferric ion as well as four uncoördinated nitrogens. Here, too, complete coördination requires polymerization although in a more complicated fashion in three dimensions only inadequately represented as follows:



etc.

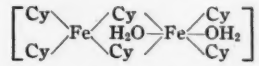
(*c*) *One-bond coördination* (*12-membered ring*).—If a single ferrocyanide ion contributes no more than one lone pair to any one iron atom, the unit becomes

Polymerization of this unit could give rise to a network of twelve-membered rings (really squares), in which the ferrous and ferric ions would occupy alternate points in a cubic lattice. A cross-section of such an arrangement is given. Only four bonds are shown in this figure, the remaining two being before and behind the cross-section and perpendicular to it.



etc.

Of these representations, (*c*) is consistent with the preliminary results of X-ray analysis published by Keggin and Miles,[9] and with the straight-line formulation of cyanide ion, :C:::N:, while (*b*) appeals because of its six-membered rings, although these would require the angular bivalent C formula for cyanide ion, :C::N::. For ordinary purposes, however, the non-committal formula, $[[Fe^{++}(CN)_6]^{\equiv}Fe^{+++}]$, is a sufficient and satisfactory representation of the unit present in the polynuclear complex of Prussian blue. Cambi and Clerici[14] have suggested a polynuclear structure similar to that given in (*a*), while Reihlen and Zimmerman[15] have suggested dismembering the ferrocyanide ion to form



These authors, however, did not adhere to the following principles which, it is submitted, are involved in the formation of such polynuclear complexes from ferrocyanide.

1. The ferrocyanide complex is stable and generally remains intact.
2. Its cyanide groups may coördinate at both ends. Since the carbons of the cyanide groups are attached to the central iron atom, the six nitrogen atoms remain to be coördinated by other metallic atoms.
3. The *N*-metal bond is relatively weak and is easily broken, for example, by alkali.
4. One, two, or three cyanide groups in a ferrocyanide ion may coördinate a single second metallic ion.

THE BERLINATES

Soluble Prussian blue may now be considered the potassium salt of a complex acid, $H^+[[Fe(CN)_6]^{\equiv}Fe]^-$, or ferri-ferrocyanic acid. For convenience, the name "berlinic acid" is suggested for this substance. This is derived from the German name for Prussian blue, which is Berlinerblau. Accordingly, soluble Prussian blue would be potassium berlinate.

When ferrocyanide is treated with excess of ferric ion, each ferrocyanide ion coördinates one ferric ion to form the univalent berlinate iron unit which is then precipitated by the excess of ferric ion as ferric berlinate, $Fe^{+++}[[Fe(CN)_6]^{\equiv}Fe]_3^-$, commonly written $Fe_4^{+++}[Fe(CN)_6]_3^{\equiv}$ (insoluble Prussian blue). If excess of ferrous ion is employed on ferricyanide ion, then each ferricyanide ion reacts with one ferrous ion to form ferric and ferrocyanide ions which combine to form the berlinate ion which is then precipitated by the excess of ferrous ion as ferrous berlinate, $Fe^{++}[[Fe(CN)_6]^{\equiv}Fe]_2^-$, or ferrous ferri-ferrocyanide, rather than the $Fe_3^{++}[Fe(CN)_6]_2^{\equiv}$, ferrous ferricyanide, commonly and erroneously cited in textbooks (Turnbull's blue). As ordinarily precipitated Turnbull's blue is a double potassium ferrous berlinate varying from $KFe(B)_3$ to $KFe_2(B)_5$.[16]

BERLINATE ION DEMONSTRATED

The representation of insoluble Prussian blue as ferric berlinate, $Fe^{+++}[[Fe(CN)_6]^{\equiv}Fe]_3$, indicates that of the four ferric ions involved in its formula, three are coördinated by the three ferrocyanide ions, while the fourth is a simple ferric ion. This relationship may be demonstrated by the experiment which is described. For the sake of analogy the less com-

[14] L. CAMBI AND A. CLERICI, *Gazz. chim. ital.*, **58**, 61 (1928).

[15] H. REIHLEN AND W. ZIMMERMAN, *Ann.*, **451**, 75 (1926); **475**, 101 (1929).

[16] E. MULLER, *J. prakt. Chem.*, (2), **84**, 241 (1911).

plicated case of silver argenticyanide is performed simultaneously.

Silver Argenticyanide	*Prussian Blue*
To 25 cc. of 0.01 *M* Ag^+.	To 25 cc. of 0.01 *M* Fe^{+++} (in tenth-formal $KHSO_4$).
Add 10 cc. of 0.02 *M* $(CN)^-$.	Add 15 cc. of 0.01 *M* $[Fe(CN)_6]^{\equiv}$ (in H_2O).
A white precipitate forms.	A blue precipitate forms.
This may be explained by: $Ag^+ + 2(CN)^- = (Ag(CN)_2)^-$, $Ag^+ + (Ag(CN)_2)^- = Ag(Ag(CN)_2)$.	This may be explained by: $Fe^{+++} + [Fe(CN)_6]^{\equiv} = [Fe{\equiv}[Fe(CN)_6]]^-$, $Fe^{+++} + 3[[Fe(CN)_6]{\equiv}Fe] = Fe^{+++}[[Fe(CN)_6]{\equiv}Fe]_3^-$.
The precipitate contains both simple silver ion and complex argenticyanide ion. The uncoördinated silver ion may be converted to argenticyanide ion by adding excess of cyanide.	The precipitate contains both simple ferric ion and complex ferri-ferrocyanide (berlinate) ion. The uncoördinated ferric ion may be converted to berlinate ion by adding excess of ferrocyanide.
Divide the suspension into two equal parts:	Divide the suspension into two equal parts:
(1) Control.	(1) Control.
(2) Add 10 cc. of 0.02 *M* cyanide; filter each part.	(2) Add 10 cc. of 0.01 *M* ferrocyanide; filter each part.
(1) yields a white residue and a cyanide-free filtrate;	(1) yields a *blue* residue and a *colorless* filtrate;
(2) yields no residue and an argenticyanide-containing filtrate.	(2) yields *no* residue and a *blue* filtrate.
In (2): $Ag^+[Ag(CN)_2]^- + 2(CN)^- = 2[Ag(CN)_2]^-$	In (2): $Fe^{+++}[[Fe(CN)_6]{\equiv}Fe]_3 + [Fe(CN)_6]^{\equiv} = 4[[Fe(CN)_6]{\equiv}Fe]$

Volzhin[17] showed by quantitative tests that as long as the ratio of ferric ion to ferrocyanide was greater than one, a precipitate was present, but that this "dissolved" as soon as the ratio became equal to unity. In 0.06 *M* solution, the end-point could be determined within 0.2 per cent. Although soluble Prussian blue does not form a true solution, nevertheless, there is a definite stoichiometric relationship between the ferric ion contained in insoluble Prussian blue and the ferrocyanide required to peptize it.

FIRST COME—FIRST SERVED

Another demonstration which suggests the coördinated nature of Prussian blue follows.

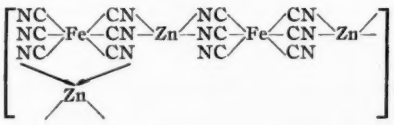
Prussian Blue	*Hatchett's Brown*
To 25 cc. of 0.01 *M* $[Fe(CN)_6]^{\equiv}$.	To 25 cc. of 0.01 *M* $[Fe(CN)_6]^{\equiv}$.
Add 25 cc. of 0.01 *M* Fe^{+++} (Ferric alum in tenth-formal $KHSO_4$).	Add 25 cc. of 0.02 *M* Cu^{++} ($CuSO_4$ in tenth-formal $KHSO_4$).
This produces a blue sol of soluble Prussian blue.	This produces a brown precipitate of Hatchett's brown.
Add 25 cc. of 0.02 *M* Cu^{++}.	Add 25 cc. of 0.01 *M* Fe^{+++}.
This produces a blue precipitate.	This causes no apparent change.

It is thus seen that two mixtures of ferrocyanide, iron, and copper ions of exactly the same composition, but prepared in different order, contain different colored precipitates, the one with the ferrocyanide apparently coördinated by ferric ion (berlinate ion), the other with the ferrocyanide coördinated by cupric ion (cupriferrocyanide ion). Whichever ion enters the supercomplex first appears to remain intrenched, for these suspensions may be kept for years without any noticeable change in appearance.

[17] V. VOLZHIN, *J. Russ. Phys.-Chem. Soc.*, **40**, 480 (1908).

OTHER COMPLEX FERROCYANIDES

The principles which have been stated above governing the formation of a polynuclear complex from ferric and ferrocyanide ions may be applied to the formulation of other complex metallic ferrocyanides. Thus, zinc ferrocyanide, $Zn_2[Fe(CN)_6]_2$, reacts with $K_4[Fe(CN)_6]$ to form $K_2Zn_3[Fe(CN)_6]_2$ (Kolthoff[7]). This formula becomes understandable when it is noted that ferrocyanide has a valence of four but supplies six nitrogen atoms for coördination, while zinc ion has a valence of two and requires four groups for coördination. Hence, the simplest ratio of zinc to ferrocyanide which will satisfy the coördination requirement is $3Zn:2[Fe(CN)_6]$, since two ferrocyanide ions supply twelve nitrogens and three zinc ions have an aggregate coördination number of twelve. The unit of the polymerized polynuclear zincoferrocyanide complex may, therefore, be written



Cupric ferrocyanide forms a complex, $K_2Cu_3[Fe(CN)_6]_2$, which is entirely analogous to the zinc complex. Ferrous ion with a coördination number of six forms $K_2Fe[Fe(CN)_6]$. Silver ferrocyanide reacts with potassium ferrocyanide to form $KAg_3[Fe(CN)_6]$. This is accounted for by silver's coördination number of two. (Ag: $2 \times 3 = 6$; ferrocyanide $6 \times 1 = 6$.) Its polynuclear complex may differ from those previously discussed in not being polymerized, thus:

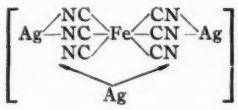


TABLE I

TABLE OF THE PRUSSIAN BLUES

Common Name	*Prepared by*	*Old Formula*	*Old Name*	*New Formula*	*New Name*
	Ferric ion on ferrocyanic acid, Oxidation of ferroferrocyanic acid Acid on soluble Prussian blue	$HFe^{+++}[Fe(CN)_6]^{\equiv}$	Hydrogen ferric ferrocyanide	$H^+[[Fe(CN)_6]{\equiv}Fe]^-$	Berlinic* acid
Soluble Prussian blue	Ferric ion on ferrocyanide Ferrous ion + ferricyanide Oxidation of ferrous ferrocyanide Reduction of ferric ferricyanide	$KFe^{+++}[Fe(CN)_6]^{\equiv}$ or $KFe^{++}[Fe(CN)_6]^{\equiv}$	Potassium ferric ferrocyanide or Potassium ferrous ferricyanide	$K^+[[Fe(CN)_6]{\equiv}Fe]^-$	Potassium berlinate*
Insoluble Prussian blue	Excess ferric ion on ferrocyanide Ferric ion on soluble Prussian blue	$Fe_4^{+++}[Fe(CN)_6]_3^{\equiv}$	Ferric ferrocyanide	$Fe^{+++}[[Fe(CN)_6]{\equiv}Fe]_3^-$	Ferric berlinate*
Turnbull's blue	Excess ferrous ion on ferricyanide Ferrous ion on soluble Prussian blue	$Fe_3^{++}[Fe(CN)_6]_2^{\equiv}$	Ferrous ferricyanide	$KFe^{++}[[Fe(CN)_6]{\equiv}Fe]_3$ or $KFe_2^{++}[[Fe(CN)_6]{\equiv}Fe]_3$	Potassium ferrous berlinate*

* Berlinate = a complex of ferric ion and ferrocyanide ion.

although a polymeric formula is also possible.

These complex ferrocyanides are produced by the theoretical quantity or excess of ferrocyanide. The so-called *normal* (or simple) ferrocyanides produced by excess of the metallic ion, such as $Ag_4[Fe(CN)_6]$ should be viewed as heavy metal salts of the complex metallic ferrocyanides; in this case, silver triargento-ferrocyanide, $Ag^+[Ag_3[Fe(CN)_6]]^-$.

SUMMARY

1. Soluble Prussian blue is $KFe^{+++}[Fe(CN)_6]^{\equiv}$ rather than $KFe^{++}[Fe(CN)_6]^{=}$.

2. The color and composition of soluble Prussian blue are accounted for by assuming polynuclear complex formation between ferric ion and the nitrogen end of the cyanide groups present in ferrocyanide.

3. This supercomplex is highly polymerized owing to stereochemical restrictions, but may be represented by its structural unit containing one ferric ion and one ferrocyanide ion, which complex, for convenience, is termed berlinate ion.

4. Insoluble Prussian blue is ferric berlinate, Turnbull's blue, ferrous berlinate, or a double potassium ferrous berlinate.

5. The composition and color of other heavy metal ferrocyanides may be accounted for by assuming polynuclear complexes based on structural units derived by considering the coördination numbers of the metals involved.

ACKNOWLEDGMENT

The author wishes to express his indebtedness to Professor Louis P. Hammett of Columbia University for helpful discussions of the theoretical matter in this paper.

TEST PAPER FOR ALUMINUM

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THE use of the ammonium salt of aurintricarboxylic acid in the final test for aluminum in qualitative analysis procedures is becoming more common.[1] In this laboratory "aluminon" test paper has been used with success for three years in the course in qualitative analysis. The advantages of the test paper are that the procedure is simplified and that students are taught to realize that tests for small quantities with small samples are possible.

The paper is prepared by soaking ashless filter paper in a 0.1 per cent. solution of the dye and also containing about one per cent. of ammonium acetate. Papers that are satisfactory are S&S No. 598, Delta No. 316, and Munktells No. 1F. Some papers are not satisfactory, among them S&S No. 601, a Tupf-Reactionspapier. This situation may be the result of the presence of a small amount of aluminum. The directions given to the students are as follows: acidify some of the filtrate which may contain sodium aluminate, sodium chromate (and sodium zincate in some procedures) with dilute HCl. Allow one drop of this solution to fall upon a piece of "aluminon" test paper. After about a minute, hold the wetted place over the open mouth of an ammonia bottle for about ten seconds. Allow the paper to dry in a clean place. After about an hour the presence of aluminum is shown by a much deeper pink spot. Sometimes the spot has a deep pink edge.

The test is possible because the Al-aurintricarboxylic acid lake is more highly colored than the dye. Phosphates and silicates, if present in relatively large quantities, may interfere by preventing the formation of the lake. Ferric ions should be absent, because a violet-purple lake is formed by them. Chromic ions also give a pink lake. The test is positive for solutions containing only one part of aluminum in three hundred thousand. A weak positive test may be due to traces of aluminum introduced from glass or porcelain ware, though this is not usually the case if Pyrex is used.

The test paper can also be used for roughly quantitative estimations of aluminum. A standard solution of aluminum chloride can conveniently be prepared by dissolving a weighed piece of aluminum in a few milliliters of concentrated hydrochloric acid. This is diluted until a concentration of 20 mg. of aluminum per liter is obtained. Aliquots of the unknown solution are acidified with HCl and diluted to known volumes until a dilution is found that will give a lighter spot than is obtained by the standard. It must be remembered that the lake is formed in acid solution (pH 4.5-5.5) and, therefore, the amounts of acid present should be somewhat comparable, so that the ammonium acetate can buffer. The lake formation takes time, and its speed is affected by temperature. Therefore, the time allowed for lake formation and the temperature should be the same for standard and unknown solution. For procedures for removing silica, iron, and phosphate and a discussion of and references on the factors influencing formation of the lake see Cox and associates.[2]

[1] REEDY, J. H., "Elementary qualitative analysis," McGraw-Hill Book Co., New York City, 1932, p. 59.

[2] Cox, G. J., *et al.*, *Ind. Eng. Chem.*, **24**, 403 (1932).

CALCULATIONS *in* HIGH-SCHOOL CHEMISTRY

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AFTER teaching high-school chemistry a few years and experimenting with a few bulletins on various types of problems, the author decided that a brief summary of all the types of problems encountered in high-school chemistry would be useful to the student and instructor. Experience has shown that both were helped materially by this ready reference.

As many of the high-school students look forward to the specialized courses in science as theoretical and mathematical "bugbears," the author has made an attempt to point out the simplicity of calculations in elementary general chemistry. In a preliminary discussion the students are told that all of the problems can be set up as simple ratios, which is demonstrated as each type comes up in the class work. This makes it possible to solve all of the problems by using only one algebraic operation—that which is commonly called "cross-multiplication." Of course, in some cases it is even easier to set them up as an ordinary problem in arithmetic.

The following illustrative material is in essentially the form in which it is mimeographed and presented to students here. This is supplemented by much class discussion and drill at the proper time. The division into two groups was made on the basis of what the author deemed essential in high-school chemistry. Complete mastery of the types in Group I is expected. There may be some criticism as to placing the gas problems in Group II, *a*. The defense is that they are derived, discussed, and demonstrated as a class project. The student is then shown how to apply the formula in a very few laboratory exercises in which it is necessary to correct a gas volume to standard conditions.

GROUP I. ESSENTIAL TYPES

1. *Formula weights* (called *molecular* weights in the case of gases and certain other types of compounds). This is the basis of many chemical problems and consists of adding up the atomic weights of all atoms represented in the formula; *e. g.*,

H_2SO_4	2H:	$2 \times 1 =$	2
	S:	$1 \times 32 =$	32
	4O:	$4 \times 16 =$	64
	Formula weight		98

It must be remembered that these atomic and formula weights are originally determined by laboratory experiment (*e. g.*, see method of type *a* under problems involving volumes of gases).

2. *Percentage composition.*—This consists of calculating the per cents. of the various elements making up a compound. (Keep in mind the fact that these are first determined analytically in the laboratory.) It is shown by the example: find the per cent. of oxygen present in sulfuric acid. From Example 1 we have the formula, H_2SO_4, representing a total weight of 98 parts or units. Since the oxygen in the compound contributes $4 \times 16 = 64$ parts of this weight, there would be $\frac{64}{98} \times 100 = 65.30$ per cent. of oxygen present. It is evident that this involves no mathematics higher than the seventh grade level.

3. *Weight problems.*—An important type of problem is the one in which we are given the weight of a substance taking part in a chemical reaction and asked to find the necessary weight of another reacting substance or product formed. These are best shown by an example: what weight of potassium chlorate is necessary to produce 20 grams of oxygen?

The first thing to do is to write the balanced equation for the reaction. Now follow the steps shown below.

Actual weight:	w grams		20 grams
Equation:	$2KClO_3$	$\longrightarrow$	$2KCl + 3O_2$
Atomic weights:	$39 + 35.5 + (16 \times 3)$		(16×2)
Formula weights:	122.5		32
Equation weights:	2×122.5		3×32

Solution:

$$\frac{w}{245} = \frac{20}{96}$$

$$96w = 245 \times 20$$

$$w = 51.04 \text{ grams}$$

Note that in this calculation it was not necessary to consider the KCl except in balancing the equation. We could have been given the weight of any of the three and could solve for either or both of the other two.

4. *Problems involving volumes of gases.*—In discussing gas volumes we use the terms *standard temperature* and *standard pressure.* The former is 273° *absolute* (0°C.), while the latter is 760 mm. These are discussed fully in connection with the gas laws of Dalton, Boyle, and Charles.

We found from our study of the gas laws that gases are made up of molecules in constant motion and that equal volumes of all gases contain equal numbers of molecules. An important application of this knowledge is in the determination of molecular (formula) weights of gases.

The weight of a liter of hydrogen under standard conditions has been determined by experiment to be 0.09 gram. The formula for hydrogen stands for a

relative weight of 2.016 based on the weight of oxygen gas at 32. If this amount (a formula or molecular weight) in grams is taken, it should occupy (2.016÷0.09) about 22.4 liters under standard conditions. We find that it actually does. Conversely, this means that if a volume of 22.4 liters is taken at standard conditions, it will be one gram-molecular weight of the gas; and by simply dropping the word gram, we have the molecular weight. Applying our knowledge of the gas laws, we see that we need only to multiply the density of any gas by 22.4, drop the word gram, and we will get the approximate molecular weight.

This quantity of 22.4 liters at standard conditions is called the *gram-molecular volume*. When a new gas is discovered, its molecular weight may be found by this method. Again the simple ratio can be set up as:

$$\frac{\text{Mol. wt.}}{22.4 \text{ liters}} = \frac{\text{Wt. (grams) of gas}}{\text{Vol. (liters) of gas (stand. condit.)}} \qquad (a)$$

or $$\text{Mol. wt.} = \frac{\text{Wt.}}{\text{Vol.}} \times 22.4 = \text{density} \times 22.4 \qquad (b)$$

Since the right-hand member of equation (*a*) is the density of the gas, this is seen (*b*) to correspond to the last statement made in the preceding paragraph. Equation (*a*) can also be used to solve for *either weight* or *volume* at standard conditions when the other two factors are given. (The 22.4 liters is constant.) Equation (*b*) can be used to find the density when the molecular weight is known.

Another very common method of calculating the molecular weight of a gas quickly when the vapor density is already known is as follows. Since from the law of Avogadro we know that all molecules occupy the same amount of space, the densities of *gases* will have the same relation as the weights of their molecules. Hydrogen is the lightest known gas and makes the simplest standard. Now, since the *vapor density* of a gas is defined as the number of times a gas is heavier than an equal volume of hydrogen under the same conditions, and since the molecular weight of the hydrogen gas is approximately 2, the approximate molecular weight of any gas can be obtained by multiplying its vapor density by two (2), the molecular weight of the standard, hydrogen; *i. e.*,

$$\text{Vapor density} \times 2 = \text{mol. wt.} \qquad (c)$$

In the past we have said that a formula represents the name of a compound, its relative composition and its reacting weight. In addition, now, the formula (when it represents a gas) stands for a volume of 22.4 liters of the gas under standard conditions of temperature and pressure. This enables us to work two types of problem which involve relations between (1) volumes of pairs of gases reacting or formed, or (2) between the weights of substances and the volumes of gases used or formed in chemical reaction. Following are examples which illustrate these two types of problem. Example 5: how many liters of oxygen would be necessary to react completely with 50 volumes (this could be any unit—cc., liters, cu. ft., etc.) of oxygen? (Note: Since in the equation H_2 stands for 22.4 liters—a gram-molecular volume—$2H_2$ represents two times 22.4 liters.)

Given: V vol. 50 vol.
Equation: $2H_2 + O_2 \longrightarrow 2H_2O$
$2 \times 22.4 \quad 22.4$

Solution: $\frac{V}{2 \times 22.4} = \frac{50}{22.4}$. Since the 22.4 will cancel out of this equation, we have $\frac{V}{2} = \frac{50}{1}$ (*d*)

which is a ratio between the reacting volumes of gases and the coefficients of the formulas of the gases in the equation. This is probably the easiest form of problem because the coefficients are generally small, whole numbers. Example 6 (weight-volume type): what weight of potassium chlorate will be needed to obtain 100 liters of oxygen?

Given: *w* grams 100 liters
Equation: $2KClO_3 \longrightarrow 2KCl + 3O_2$
$2 \times 122.5 \quad 3 \times 22.4$

Solution: $\frac{w}{2 \times 122.5} = \frac{100}{3 \times 22.4}$

$w = 364.3$ *grams*

GROUP II. SUPPLEMENTARY CALCULATIONS

The fact that some of the calculations have been segregated and put under the heading *Supplementary* does not mean that they are relatively unimportant. However, we are not often called upon to use these in the general high-school course. Very little explanation accompanies the word-formulas, since a complete discussion of all but the first type may be found in any physics text. Types 2 to 5 involve only physical principles and are generally taken up in detail in a course in physics. Their solution involves only the most elementary arithmetic.

1. *Determining simplest formulas for compounds.*[1]—To determine the simplest formula for a compound (which is what we generally use in inorganic chemistry), we need only to know the percentage composition by weight and the atomic weights of the elements in combination. The former are determined analytically in the laboratory. Example 7: a compound is found by experiment to contain: sodium, 32.4+%; sulfur, 22.5+%; and oxygen, 45+%. What would be the simplest formula for this compound?

	Composition	*At. Wt.*	*Ratio of No. of Atoms*		*No. Atoms*
Na	32.4+%	23	1.4	Now divide each ratio	2
S	22.5+%	32	0.7	by the smallest, 0.7	1
O	45.0+%	16	2.8		4

FORMULA: Na_2SO_4

Frequently, the number of atoms does not come out an integer. Since we must represent whole atoms in our formula, multiply each by the smallest whole number that will give a whole number for the subscript of each element in the formula.

2. *Gas problems.*—One good method of solving this

[1] See GRIFFIN, CARROLL W., "Calculation of simplest formula from percentage composition," J. CHEM. EDUC., 10, 575 (Sept., 1933).

type of problem is to use the derived formula, $\frac{PV}{T} = \frac{P'V'}{T'}$ in which T represents the first temperature (absolute); T', the second temperature; P, the first pressure; P', the second pressure; V, the first volume; and V', the second volume. If one of the factors remains unchanged throughout the problem (*e. g.*, T and T'), it may be canceled out of the formula. Since we use this in chemistry to calculate the volume of gas under standard conditions which we have measured under laboratory conditions, the formula becomes $\frac{PV}{T} = \frac{760\ V'}{273}$. If the problem involves the collection of a gas over water, the pressure of the water vapor (aqueous tension) must be subtracted from the first pressure. If there is a difference in levels of the collecting liquid, correction must be made. Example 8: 12.9 liters of a gas are under a pressure of 770 mm. at a temperature of 17°C. The gas is collected over water. The vapor pressure at 17°C. is 14 mm. The volume is to be calculated at standard conditions in order to use it in determining the molecular weight of the gas. What is the new volume?

Solution: $\frac{(770 - 14)12.9}{17 + 273} = \frac{760\ V'}{273}$

$V' = 12.08$ *liters*

3. *Density.*—Solids and liquids are weighed in grams and measured in cubic centimeters. Gases are weighed in grams and measured in liters.

$$\text{Density} = \frac{\text{wt. of substance}}{\text{vol. of substance}}$$

4. *Specific gravity.*—

(a) Solids and liquids:

$$\text{Sp. gr.} = \frac{\text{wt. of substance}}{\text{wt. of equal vol. of water}}$$

(b) Gases:

$$\text{Sp. gr.} = \frac{\text{wt. of gas}}{\text{wt. of equal vol. of air}}$$

5. *Vapor density* (gases and vapors).—

$$\text{Vapor density} = \frac{\text{wt. of gas or vapor}}{\text{wt. of equal vol. of } H_2}$$

GEORG BREDIG*

A CHEMIST achieves eminence first, from his discoveries of new materials, properties, or relationships; second, by devising new methods of research; third, by developing his students and co-workers into competent investigators. Georg Bredig, one of the outstanding physical chemists of our time, has derived lasting influence in all these ways.

After passing through the orthodox training in chemistry and physics (1886–89) at Freiburg and Berlin, he was irresistibly drawn to Leipzig, which was becoming an international center for the propagation of the new border science, physical chemistry. In 1889 Bredig enlisted in that company of brilliant young men surrounding Ostwald and soon knew that he had found the branch of chemistry most congenial to his talents. Finishing his doctorate in 1894 he rounded off his training by a year with van't Hoff in Amsterdam, followed by shorter stays with Berthelot in Paris and Arrhenius in Stockholm.

Recalled to Leipzig, he acted as Ostwald's assistant until 1901, when he went to Heidelberg as professor. In 1910 he accepted a call to Zurich, but within a year he became Haber's successor as head of the Institute of Physical and Electrochemistry at Karlsruhe, a responsibility which he filled with honor until his retirement from academic life in 1933.

The record of this active life of devotion to the cause of chemistry and education is set down in some two hundred publications. Here may be found the announcements of his discoveries significant both to chemistry and other sciences, the clarification of old difficulties, the ground work of important industrial processes, and novel and far-reaching approaches to new fields of chemical inquiry. A mere list of the main topics that have occupied him and his students testifies to the calibre of the output of his laboratory: inorganic ferments; stereochemical asymmetric catalysis; adiabatic reaction kinetics; amphoteric electrolytes and ampholytic ions; electrochemistry; organic and inorganic catalysts; kinetics of diazo-acetic ester.

He has been honored by universities and learned societies, but none of his medals, honorary memberships, and degrees are as dear to this kindly, generous, gentleman as the reverence in which he is held by his former students and collaborators, whose success he counts as no small part of his own reward.

(*Contributed by Ralph E. Oesper,*
University of Cincinnati.)

* See frontispiece.

A SURVEY *of* CHEMISTRY *in* WOMEN'S COLLEGES

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EDUCATING a woman in chemistry may have one of two purposes. It may be a means of furthering her liberal education. Her outlook of the influence of a physical science will be extended. Or, on the other hand, as a professional subject, it may offer a means of livelihood. The purely cultural side will be omitted in this article, even though the author agrees that more can be accomplished by the attitude of the instructors than by details of a curriculum.

In connection with the teaching of chemistry to women, the statement, "The assumption that women are human beings, interested in cultural acquisitions, is more important than an assumption that the future of chemical learning depends upon them," has been made. The present study has been undertaken on account of disagreement, at least in part, with this idea. The Women's Service Committee of the American Chemical Society compiled a list[1] of books and articles for women interested in chemistry as a profession. This list includes some papers on required training. The part played by the women's college in that training has not been emphasized. To ascertain the nature and extent of the chemical training in women's colleges is the main purpose of the survey.

In this survey the curricula of the women's colleges have been studied relative to chemistry courses offered; some textbooks used; laboratory fees; degrees granted and science courses required for the same; chemistry and other requirements for chemistry majors; recommended courses for majors; enrolment in chemistry; and the chemistry faculty and research.

The data for this study were obtained by questionnaire. All four-year women's colleges in the United States were asked to coöperate. Of these, eighty-one* replies based on the work of the 1934-35 school year were received. For further data the college catalogs of twenty additional colleges were consulted. This resulted in a maximum of one hundred one replies being available for tabulation for any one item. The resulting information should be significant because it includes curricula which affect more than 41,497 students, the enrolment in eighty women's colleges.

Presented before the Division of Chemical Education at the Ninety-second meeting of the A. C. S., Pittsburgh, Pennsylvania, September 10, 1936.

[1] *Ind. Eng. Chem., News Edition*, Vol. 14, No. 10.

* List is found at the end of the article.

CHEMISTRY COURSES

As seen from Table 1, there are many kinds of chemistry courses offered. They probably differ sufficiently in nature that it is safe to say eighty various courses are given.

The general inorganic chemistry has been divided into three groups (1) colleges in which all students take the same course; (2) colleges with a separate course for students without previous chemical training; and (3) colleges with separate courses for students with previous chemical education. The majority of colleges still give but one course in general chemistry. Also the prevalent length of the general chemistry course is two semesters.† Only a few colleges give inorganic chemistry intended for specialized groups.

TABLE 1

COURSES OFFERED IN CHEMISTRY DEPARTMENTS

	Total No. of Colleges	*No. of Colleges*	*No. of Semesters*
GENERAL CHEMISTRY			
For all students	76	8	1
		65	2
		1	3
		1	4
For beginners	33	2	1
		31	2
For students with previous training	28	7	1
		20	2
Advanced inorganic chemistry	20	10	1
		8	2
		1	3
Inorganic preparations	7	6	1
General chemistry for biologists	4	1	1
		2	2
General chemistry for nurses	1	1	1
Pandemic	1	1	1
INORGANIC ANALYTICAL			
Qualitative analysis	93	1	2/3
		71	1
		2	1 1/2
		16	2
Advanced qualitative	11	9	1
		1	2
Elementary quantitative	91	1	2/3
		63	1
		1	1 1/2
		23	2
Advanced quantitative	35	1	2/3
		20	1
		12	2
		1	Arranged
Analytical	6	1	1
		5	2
Microscopic qualitative	3	2	1
Quantitative methods	3	1	2/3
		2	1
Technical analysis	2	1	1
		1	2
Mineral analysis	2	2	Arranged

† Wherever units of credit are mentioned, the basis used is one hundred twenty units for graduation in a period of eight semesters, or four years.

TABLE 1 (*Continued*)

	Total No. of Colleges	*No. of Colleges*	*No. of Semesters*
INORGANIC ANALYTICAL (*Continued*)			
Microanalysis	2	2	1
Gas analysis	2	1	1
Instrumental analysis	1	1	1
Water analysis	1	1	1
Volumetrics	1	1	1
Analytical and theory	1	1	2
ORGANIC CHEMISTRY			
Elementary organic	100	12	1
		85	2
		1	3
Advanced organic	38	21	1
		1	1 1/3
		13	2
Qualitative organic	11	8	1
		2	2
Advanced organic laboratory	4	2	1
		2	2
Organic laboratory	6	4	1
		2	2
Organic preparations	6	4	1
		1	2
Pigments and dyes	1	1	1
Organic synthesis and analysis	1	1	1
Topics of organic	1	1	1
APPLIED ORGANIC CHEMISTRY			
Physiological	58	2	2/3
		37	1
		16	2
Food	43	1	2/3
		32	1
		8	2
Food analysis	4	3	1
		1	2
Textiles	2	2	1
Food and physiological	2	1	6
		1	1
Plant and animal tissue	1	1	1
Advanced food analysis	2	2	1
Air, water, and food analysis	1		
Sanitary	1	1	1
Food and plant	1	1	1
Metabolism	1	1	1
Advanced physiological	2	2	1
Practical and sanitary analysis	1	1	1
Nutrition	1	1	2
Biochemical methods	1	1	2
Clinical laboratory methods	1	1	2
Blood chemistry	1	1	1
Food and nutrition	1	1	1
Household	7	5	1
Home economic study	1	2	2
EDUCATION AND LITERATURE			
Teaching of chemistry	38	1	2/3
		27	1
		1	1 1/2
		4	2
Practice teaching	1	1	1
History of chemistry	33	23	1
		9	2
Seminar	11	5	1
		4	2
		1	4
Problems	5	2	1
		3	2
Research	5	2	1
		2	2
		1	Arranged
Selected topics	3	1	1
		1	2
Thesis	2	1	2
Chemical point of view	1	1	1
Experimental methods	1	1	1
Chemical literature	1	1	1
Reading course	1	1	2
General science current events	1	1	1
Contemporary	1	1	1
PHYSICAL CHEMISTRY			
Physical	71	1	2/3
		32	1
		37	2
		1	3
Colloid	6	6	1
Radioactivity and atomic structure	4	3	1
		1	2
Advanced physical	3	1	1
		1	2
PHYSICAL CHEMISTRY (*Continued*)			
Experimental physical	3	1	1
		1	2
Physical for premedics	1	1	1
Modern electrical theories	1	1	1
Electrical measurements	1	1	1
Hydrogen-ion determinations	1	1	1
Hydrogen-ion and potentiometric titrations	1	1	1
Physico-chemical measurements	1	1	1
APPLIED CHEMISTRY			
Industrial	10	4	1
		3	2
		1	4
Applied	6	3	1
		3	2
Metallurgy	2	2	1
Fire assay	1	1	1
COMBINED COURSES			
Inorganic and qualitative analysis	1		
Inorganic and physiological	1	1	Arranged
Qualitative and quantitative	1	1	2
Quantitative and elementary physical chemistry	1	1	2
Organic and physiological	2	2	2
Organic and food	2	1	1
		1	2
Organic analysis and physical	2	1	1

In analytical chemistry it is found that one semester of qualitative analysis and one semester of quantitative analysis meet the requirements of the colleges. As will also be noted in other divisions of advanced chemistry, the more specialized courses in analytical work are given by only a few colleges. The reasons may be to satisfy the economic need of the particular community or to give the students a chance to work under experts in those fields.

Of the remaining fields the time devoted to the courses more widely given are: elementary organic chemistry, two semesters; physiological, one semester; food, one semester; teaching of chemistry, one semester; history of chemistry, one semester; and physical chemistry, one or two semesters.

A number of different courses are included under the heading of education and literature. The teaching of chemistry is stressed at quite a number of colleges, while the history of chemistry runs a close second in popularity. Seminars have gained popularity in undergraduate work and seem an excellent means through which some courses as "Chemical Literature, Selected Topics," and others might be given.

The industrial field is studied at a few colleges, but undoubtedly as an informative, rather than a technical, subject.

Under the title of "Combined Courses" several allied courses are offered in the same year. Some of them are logically associated, while others could easily be listed as separate integral courses.

TABLE 2

COURSES, LECTURES, LABORATORY WORK, SEMESTERS, CREDIT HOURS

	No. of Colleges	*No. of Lectures per Week*	*No. of Lab. Hrs. per Week*	*No. of Semesters*	*Total No. of Credit Hrs.*
GENERAL CHEMISTRY					
For all students	13	3	4	2	4, 5, 6, 8, 10, 15
	13	3	3	2	4, 6, 8
	7	2	3	2	6

TABLE 2 (*Continued*)

GENERAL CHEMISTRY (*Continued*)					
	5	2	4	2	8
For all students	5	3	2	2	4, 6, 8
	3	2	2	2	6
	2	3	6	2	10
	2	3	4	1	5
	2	3	3	1	3, 4
	2	3	2.5	1	8
	1	4	4	1	6
	1	3	5	2	10
	1	3	4	1/3	6⅔
	1	3	1	2	6
	1	2	5	1	5
	1	2	4	3	12
For beginners	13	3	3	2	3, 6, 8
	3	3	4	2	6, 9, 15
	2	2	4	2	6, 8
	2	2	3	2	6
	2	2	2	2	6
	1	3	4 or 7	2	6 or 8
	1	3	2.5	2	6
	1	3	2	2	8
	1	3			
	1	2	4	1	
For students with previous training	6	3	3	2	6, 8
	4	3	4	2	6, 8, 15
	4	2	3	2	6
	3	3	3	1	3
	2	2	4	2	6, 8
	1	4			
	1	3	4 or 7	2	6 or 8
	1	3	4	1	4
	1	3	2	2	8
	1	2	2	2	6
Advanced inorganic	5	3	6	1	3, 6
	2	3	0	2	6
	1	3	3	2	8
	1	3	3	1	3
	1	2	9	1	5
	1	2	0	2	4
	1	2	3	2	6
	1	2	3	1	3
	1	2	4	1	3
	1	3	2	2	4
	1	1	6	1	3
	1	2	4	2	8
INORGANIC QUALITATIVE	15	2	6	1	3, 4, 5
	8	2	4	1	3, 4
	8	1	6	1	3, 6, 9
	6	2	6	2	6, 8, 10
	4	3	4	1	1, 4, 5
	4	1	4	1	3, 5
	3	3	6	1	5, 6
	2	4	4	1	6
	2	2	5	1	3
	1	2	9	1	5
	1	1	3	1	3
	1	2	8	1	3⅓
	1	2	3 or 9	1	3 or 5
	1	2	3	1	3
	1	3	3	1	4
	1	2	6 or 8	1	4 or 5
	1	2	4	2	8
	1	1	7.5	1	4
	1	2	2	2	6
	1	1	5	1⅓	6
	1	2	6	⅔	1⅓
	1	3	4	2	5
	1	1	4	1	3
	1	1	4	2	6
QUANTITATIVE ANALYSIS	11	1	6	1	3, 4, 6
	9	2	6	1	2.5, 3, 4, 5
	4	2	6	2	6, 8
	4	2	4	1	3, 4
	3	3	6	1	5, 6
	2	3	4	1	4, 5
	2	1	4	1	3, 6
	2	1	8	2	8, 10
	2	1	6	2	6, 8
	2	2	8	1	6
	2	1	4	2	6
	1	3	6	1⅓	8
	1	3	6	2	
	1	2	9	1	5
	1	3	3	1	4
	1	2	8	2	6⅔
	1	2	6 to 8	1	4 to 5
	1	2	3 to 9	1	3 to 5
	1	1	7.5	1	4
	1	1	5	⅔	4
	1	1	12	1	5

QUANTITATIVE ANALYSES (*continued*)	1	1	8	1	3
	1	1	3	1	2
	1	2	5	1	3
	1	½	8	1	1⅓
	1	1	9	1	4
	1	2	6	1 or 2	1 or 2
ADVANCED QUANTITATIVE	4	1	6	1	3, 6
	3	1	6	2	6, 8
	2	2	6	1	3
	1	3	6	1	4
	1	2	9	1	5
	2	2	6	2	6
	1	1	6 or 9	1	2 or 3
	1	1	3	1	2
	1	1	5	1	3
	1	1	6 or 10	2	4 or 6
	1	1	6	⅔	4
	1	1	3 or 6	2	4 or 6
	1	1	3	1	2
	1	1	2 or 4	1	2 or 4
ORGANIC	15	3	3	2	6, 8, 9
	12	3	4	2	4, 6, 6⅔, 8 10, 15
	9	2	3	2	6, 11
	8	2	4	2	6, 8
	3	3	6	2	8, 10, 12
	3	2	6	2	8
	2	3	6	1	5
	2	3	2	2	8
	2	3	3	1	3, 4
	2	2	2	2	6
	2	2	6	1	2.5, 6
	2	2	2	1	3
	1	3	4	1	3
	1	3	3 or 6	2	6
	1	3	3 or 4	2	6 or 8
	1	3	2½	1	4
	1	3	4 or 6	2	8 or 10
	1	3	8	1	1½
	1	3	5	2	8
	1	2 or 4	0 or 4	2	4 or 6
	1	2	4	3	12
	1	2½	5	1	5
	1	2	4	1	4
	1	1	6	2	6
ORGANIC QUALITATIVE	2	1	6	1	3
	1	3	3	2	4
	1	1	6	2	6
	1	1	4	1	3
ADVANCED ORGANIC	3	2	3	1	3
	2	2	4	1	3, 4
	2	1	2	1	3
	2	1	6	1	3
	1	2	3, 6, or 9	2	6, 8, or 10
	1	3	3	1	4
	1	3	6	2	12
	1	3	4	2	6
	1	3	6	1	4
	1	2	6	1⅓	2⅔
	1	2	6 or 7	1	3
	1	2	2	1	3
	1	2	5	1	4
	1	2	6	2	8
	1	2	6 or 10	2	4 or 8
	1	1	8	¼	3⅓
	1	1	6	2	6
	1	1	3	2	2
FOOD AND NUTRITION	3	2	4	1	4
	3	2	3	1	3
	2	2	5	1	3
	2	1	6	1	3
	1	3	4	1	3⅓
	1	3	6	1	5
	1	3	3	1	4
	1	3	4	⅔	5
	1	3	4	¼	3⅓
	1	2	2	1	3
	1	2	4	2	6
	1	1	5	1	3
	1	1	9	1	4
	1	1	7	2	4
PHYSIOLOGICAL	4	2	6	1	4
	4	2	4	1	3, 4
	3	2	2	1	3
	3	2	5	1	3, 4
	3	2	4	2	6
	2	3	3	1	3
	2	3	4	1	3, 3⅓
	1	3	4	2	8
	1	3	2	1	4
	1	3	4	⅓	3⅓

TABLE 2 (*Continued*)

	No. of Colleges	No. of Lectures per Week	No. of Lab. Hrs. per Week	No. of Semesters	Total No. of Credit Hrs.
PHYSIOLOGICAL (*Continued*)					
	1	2	3	1	3
	1	2	4	2/3	4
	1	2	1	2	6
	1	2	3	2	6
	1	1	6	1	3
	1	1	6	2	6
	1	1	4	1	3
	1	1	4	2	6
TEACHING OF CHEMISTRY	9	2	0	1	2, 3
	7	3	0	1	1/2, 3
	1	3	0	2/3	3
	1	2	4	1	3
	1	2	2	1	3
	1	2	3	1	3
	1	1	0	2	1
SEMINAR	3	1		2	2
	2	3		1	3
	1	1		1	1
	1	3		1 or 2	1 or 2
HISTORY OF CHEMISTRY	8	3		1	3
	5	1		2	2
	1	2		2	4
	1	4		1	4
	1	2		2	2
PHYSICAL	7	3	3	2	6, 8, 9
	6	2	3	2	6
	4	2	3	1	2, 3
	3	3	0	2	6, 8
	2	3	6	2	8, 10
	2	3	0	1	3
	2	3	4	1	3, 4
	2	2	2	1	3
	2	3	3	1	3
	2	2	4	1	4
	1	3	6	1	5
	1	4	0	1	4
	1	3	2	2	8
	1	3	4	3	9
	1	1	6	2	6
	1	1	4	2	6
	1	3	5	1	5
	1	2	0	1	2
	1	2	2	2	6
	1	1 1/2	3	1	3
	1	2	4	2/3	4
	1	2	2 1/2	2	6
	1	2	6	1 or 2	4 or 8
	1	3	4	2	10
	1	2	0	2	4
COLLOID CHEMISTRY	1				
	1	2	6	1	5
	1	2	3	1	3
	1	2	2	1	3
	1	1	3 or 6	1	2 or more
	1	1	6	1	
APPLIED CHEMISTRY	2	3	3	1	3
	1	3	6	1	6
	1	3	2	2	6
	1	3	0	2	6
	1	2	3	2	4
	1	2	3	1	3

Without thought of standardization of course work, but merely for information of faculties in women's colleges, Table 2 has been compiled. Examination of questionnaire returns indicated a considerable diversification in number of lectures and laboratory hours per week, as well as the number of semesters and total units of credit. Supposedly, units of credit are so apportioned as to allow one unit per hour of lecture a week for one semester. In addition, one unit is ordinarily allowed for each two to three hours of laboratory work per week per semester. Table 2 shows that the above method of accrediting is not used. Some give no credit for laboratory work, while others award ample credit. The transfer of credits from one college to another or to graduate school must be tedious.

Under the heading of Total Number of Credit Hours of Table 2, the figures show the variously allowed number of credit hours. The table does not attempt to show how many colleges permit certain credit in preference to another amount. For example, the first item in the table is marked 4, 5, 6, 8, 10, 15. This does not mean that four or some other number is the prevalent credit given. It indicates only the variety of credits allowed for the entire course irrespective of the number of semesters.

TEXTBOOKS

It would not be practical to make a study of all textbooks used in chemistry in its various phases in women's colleges. It was thought sufficient to inquire about the textbook and laboratory manual used in the course taken by most students, *i. e.*, inorganic chemistry. Table 3 lists authors in code along with the number of adoptions and approximate number of students enrolled. Some colleges used two texts in inorganic chemistry. Thus the assumption was made that half used one text and the other half the other text.

It is quite evident that almost fifty per cent. of the students use one of two texts, each of which is widely used in men's colleges. The manuals which accompany these texts are used by large groups of students. It is interesting and significant to find twenty colleges using their own laboratory manuals.

Since fifty-five colleges use two very frequently adopted texts, it may be inferred that they, likewise, employ standard texts and reference books in their advanced courses.

FEES

In studying the amount of laboratory work done in various courses the question of fees per semester naturally arises. To state that the average two-hour laboratory fee is \$7.90, while for a twelve-hour period the fee is only \$7.50, would not be entirely true. For that reason detailed information concerning fees for both elementary and advanced courses with laboratory periods of various lengths, found in Table 4, is included. Laboratory courses ranging from two to twelve hours are studied with the number of colleges, charging certain fees, listed opposite those fees.

TABLE 3

TEXTBOOKS AND MANUALS USED IN GENERAL CHEMISTRY

	TEXTBOOKS					MANUALS	
Code Number of Authors of Textbooks and Manuals Used	Beginning Group	Offering Group	Both Groups	Total No. of Colleges	No. of Students Enrolled in Course	No. of Colleges	No. of Students Enrolled in Course
1	3			3	67	3	57
2	3	2	8	13	488	6	317
3	6	4	4	14	712		
4	3	3	13	19	1144	8	803
5		4	15	26	1198	11	964
6	2	1	3	6	333	1	29
7	2	4	5	9	605	3	108
8		1	1	2	86	1	47
9			1	1	23		
10			1	1	193	1	193
11	2			2	57		
12			1	1	74		
13			1	1	30	1	30
14			1	1	75	1	75
15			1	1	45	1	45
16		1		1	11		

TABLE 3 (*Continued*)

17	1		1	59		
18		1	1	72	1	72
No text		2	2	190		
TOTAL			105	5462		
19					1	12
20					1	12
21					1	16
22					7	173
23					1	90
24					6	303
25					1	
26					2	411
27					1	71
28					1	46
29					1	62
Own direction					20	1681
TOTAL					81	5617

TABLE 4

LABORATORY FEES PER SEMESTER

Fees per 2 Hr. Week	*No. of Colleges*	*Fees per 3 Hr. Week*	*No. of Colleges*	*Fees per 4 Hr. Week*	*No. of Colleges*	*Fees per 5 Hr. Week*	*No. of Colleges*
$ 1.50	1	$ 2.00	2	$ 1.50	1	$ 3.50	2
2.50	5	2.50	1	2.50	4	3.66	1
3.00	4	3.00	6	3.00	3	5.00	6
3.50	2	3.50	4	3.50	3	6.00	2
4.00	4	4.00	10	4.00	4	7.50	3
4.50	4	4.50	1	4.25	1	8.00	1
4.80	1	5.00	32	4.50	5	10.00	2
5.00	8	6.00	2	5.00	37		
5.50	1	6.25	1	7.00	1		
7.50	2	7.00	7	7.50	26		
8.00	2	7.50	20	10.00	11		
9.00	1	8.00	5	11.00	1		
10.00	16	8.50	1	12.50	8		
12.50	2	10.00	13	15.00	5		
15.00	1	15.00	11				
20.00	1						
25.00	1						
TOTAL	56		116		110		17

Fees per 6 Hr. Week	*No. of Colleges*	*Fees per 7 Hr. Week*	*No. of Colleges*	*Fees per 8 Hr. Week*	*No. of Colleges*	*Fees per 9 Hr. Week*	*No. of Colleges*
$ 2.00	1	$ 4.00	1	$ 5.00	2	$ 3.00	3
2.50	2	5.50	2	10.00	2	4.00	1
3.00	2					5.00	3
3.50	7					7.00	2
4.00	7					7.50	7
5.00	25					8.50	1
6.00	2					10.00	5
6.25	1					11.00	1
7.00	8					15.00	1
7.50	21						
8.00	2						
8.50	5						
10.00	12						
11.00	1						
12.00	1						
12.50	12						
13. 0	1						
15.00	14						
TOTAL	124		3		4		24

Fees per 10 Hr. Week	*No. of Colleges*	*Fees per 12 Hr. Week*	*No. of Colleges*
$ 5.00	2	$ 7.50	2

Average Fees

2 hr.	$ 7.90
3 hr.	6.93
4 hr.	6.88
5 hr.	6.07
6 hr.	8.04
7 hr.	5.00
8 hr.	7.50
9 hr.	7.46
10 hr.	5.00
12 hr.	7.50

There is no apparent parallelism between the length of the laboratory period per week and the corresponding fees. It may be expected that a short period of laboratory work may require as much apparatus as a longer period, but at the same time it may be expected that the longer, more advanced, courses consume more expensive chemicals and larger quantities of them.

DEGREES

Sometimes in the process of deciding whether or not to attend a woman's college to major in a science, *e. g.*, chemistry, the question of degrees offered arises. For that reason Table 5 has been incorporated. As shown therein, the Bachelor of Arts degree is granted more frequently than the Bachelor of Science degree. Only a small number of women's colleges, generally the larger ones, grant either the Master of Arts or Master of Science degree. No women's colleges, aside from those affiliated with a university, offer the degree of Doctor of Philosophy.

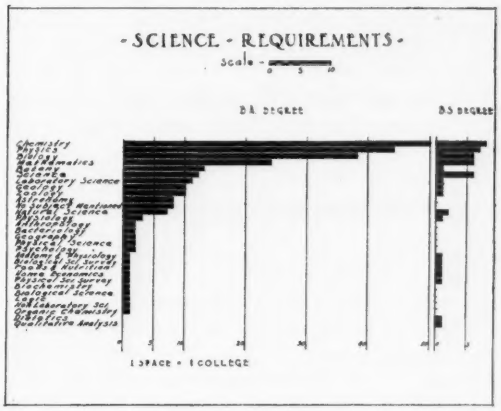

FIGURE 1

It is imperative that the study of degrees includes consideration of degree requirements. The natural science requirements for all students for both the A.B. and B.S. degrees were tabulated and for clarification plotted in Figure 1. The various catalogs and questionnaires stipulated, in most cases, a definite number of units of several mentioned sciences. The choice of sciences varied with different colleges. Figure 1 was plotted by counting the frequency with which the various sciences were offered in fulfilment of science requirements for graduation. It is apparent that the most frequently required subjects for the A.B. degree are consecutively chemistry, physics, biology, and mathematics, with one more addition of "Science" when the student is working for the B.S. degree.

It will also be noted that two subjects infrequently classed with the natural sciences may be offered in lieu of the science requirements. They are psychology and logic.

Naturally, more science is required of students qualifying for the B.S. degree than for the A.B. degree.

Averaging the credits for seventy-four colleges, it was found that 9.5 credit hours of science were specified for qualification for the A.B. degree. In twenty-three colleges offering the B.S. degree the average requirement of science was 19.5 credit hours.

TABLE 5

DEGREES OFFERED. THESES

96 college records used, 80 of which returned questionnaires
45 colleges offer A.B. degree only
24 colleges offer B.S. degree only
27 colleges offer A.B. and B.S. degrees
4 colleges offer A.B. and M.A. degrees
2 colleges offer B.S. and M.A. degrees
2 colleges offer A.B., B.S., and M.S. degrees
2 colleges offer A.B., B.S., M.A., and M.S. degrees
or
72 colleges offer A.B. degree
51 colleges offer B.S. degree
8 colleges offer M.A. degree
4 colleges offer M.S. degree
2 colleges offer Ph.D. degree (affiliated with universities)

THESES

2 colleges require theses for the A.B. degree
3 colleges require theses for the B.S. degree
3 colleges require theses for the A.B. and B.S. degrees

CHEMISTRY AND ALLIED COURSES FOR MAJORS

What courses in chemistry and allied subjects should be taught to chemistry majors in a woman's college? An attempt to answer the question can be made by setting a goal or standard. That standard may be the courses taught in men's colleges, the courses requested by industry, or the courses essential for unconditional entrance into a university to do graduate work in chemistry. The latter method was employed. The heads of chemistry departments of fifteen leading graduate schools were asked to furnish entrance requirements. These requirements are found in Table 6. With the exception of two institutions, the courses are very much the same. Because of this uniform requirement for measuring the undergraduate courses in women's colleges, the following chemistry courses were chosen as the standard, *viz.*, one year of inorganic chemistry; one semester of qualitative analysis; one year of quantitative analysis; one year of organic chemistry; and one year of physical chemistry.

In order to determine whether colleges prepare students for graduate schools, the above chemistry courses and their allotted semester periods were tabulated in Table 7, as well as the number of colleges requiring various courses of different lengths of time. It will be seen that two colleges require a semester more of work than is necessary, eight require just sufficient work, and the remaining sixty-two are deficient in their requirements. Some, however, are deficient by only a semester of one subject and in turn require more than is demanded in other phases. It must not be inferred that the colleges give only as much chemistry as they require of their majors.

The women's colleges offer more courses, which are listed in Table 8 in a manner similar to Table 7. Here we find twenty-one colleges offering sufficient chemistry to enter graduate school, while twenty-five are lacking but one semester.

Other chemistry courses, as previously mentioned, are offered. So the accusation that women's colleges give insufficient work to justify a major in chemistry is unfounded. The above method of gaging colleges by graduate requirements is not entirely satisfactory and does not warrant undue emphasis.

The graduate schools request knowledge in allied fields such as mathematics, physics, French, and German. In turn the women's colleges require that these subjects be taken, as found in Table 9. Out of eighty colleges, fifty-nine compel the major to take additional

TABLE 6

ENTRANCE REQUIREMENTS INTO GRADUATE SCHOOLS

Graduate School Code Nos.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1 yr. Inorganic Chemistry	x	x	Not by courses but by ability	x	x	x	x	x	x	x	x	x	x	No stipulated requirements	x
1 sem. Qualitative Analysis	x	x		x	x	x	x	x	x	x	x	x	x		x
1 yr. Quantitative Analysis	x	x		x	x	x	x	x	x	1 sem.	x	x	x		x
1 yr. Organic Chemistry	x	x		x	x	x	x	x	x	x	x	[1]	x		x
1 yr. Physical Chemistry	x	x		x	1 sem.	x	x	x	x	x	x	[2]	x		x
Mathematics through Calculus	x	x		x				x	x	x	x				
1 yr. Physics	x	x		x				x	x		x				
French								x				x			
German								x	x			x			
Thesis															x
Advanced Chemistry											[2]	[3]			
1 sem. Chemical Calculation					x										
Humanities									x						
English Composition and Literature									x						

[1] 14 hrs. per week for a year.
[2] Advanced work in Inorganic, Organic, and Physical Chemistry.
[3] Advanced Organic Chemistry, particularly combustions.

TABLE 7

CHEMISTRY REQUIRED OF MAJORS

No. of Colleges	*1 Yr. Inorganic*	*1 Sem. Qualitative*	*1 Yr. Quantitative*[1]	*1 Yr. Organic*	*1 Yr. Physical*
2	x	1 yr.	x	x	x
8	x	x	x	x	x
1	x	x	1 sem.	1½ yr.	1½ yr.
1	1½ yr.	x	x	2 yr.	1 sem.
1	x	x	1½ yr.	x	1 sem.
1	x	x	x	1½ yr.	1 sem.
8	x	x	1 sem.	x	x
1	1 sem.	x	x	x	x
2	x	x	x	x	1 sem.
2	x	x	1 sem.	x	1 sem.
1	x	x	1 sem.	1 sem.	1 sem.
1	x	1 yr.	x	1½ yr.	
2	x	x	x	1½ yr.	
6	x	1 yr.	x	x	
1	x	1 yr.	1 sem.	x	
1	x		x	x	x
6	x	x	x	x	
1	x		x	x	1 sem.
14	x	x	1 sem.	x	
1	1 sem.	x	x	x	
1	x		1½ yr.	1½ yr.	
1	x	x	1½ yr.		
1	x		x	x	
1	x	1 yr.		x	
1		1 yr.	x	x	
2	x	x		x	
1	x		x	1 sem.	
1	x	x	x		
1	x		1 sem.	x	
1			1 sem.	1 sem.	

[1] One semester or more of biological chemistry or food chemistry counts for one semester of quantitative analysis.

work. In most cases they suggest more than one subject, but do not require over fourteen hours of credit altogether. This amounts to two years of one subject, or to a year of each of two subjects, which is insufficient to satisfy graduate schools as indicated in Table 6.

TABLE 8

CHEMISTRY OFFERED TOWARD GRADUATE SCHOOL ENTRANCE

No. of Colleges	*1 Yr. Inorganic*	*1 Sem. Qualitative*	*1 Yr. Quantitative*	*1 Yr. Organic*	*1 Yr. Physical*
21	x	x	x	x	x
16	x	x	x	x	1 sem.
15	x	x	x	x	
9	x	x	1 sem.	x	x
8	x	x	1 sem.	x	
8	x	x	1 sem.	x	1 sem.
2	x			x	x
2	x	x		x	x
1	x	x	x	1 sem.	1 sem.
1	x		x	x	x
1	x	x			
1	x	x	arrange	x	1 sem.
1	x	x	x	x	2/3 sem.
1	x			1 sem.	
1	x	x	1 sem.	1 sem.	1 sem.
1	x	x	1 sem.	x	elective
1	1 sem.	x	x	x	
1	1 sem.	x	x	x	x
1	1 sem.	x	x	1 sem.	1 sem.
1	1 sem.	x			
1	x	x	x	1 sem.	
1	x	x	x	1 sem.	x
1	x			x	
1	x		?	?	
TOTAL 97					

TABLE 9

ADDITIONAL REQUIREMENTS FOR MAJORS

Courses	*No. of Colleges*	*Average Units of Credit*
Mathematics, Physics	16	8.3
Physics	9	6
Mathematics, Physics, Biology	8	11
Mathematics, Physics, French, German	6	9
Mathematics, any science	3	10
Physics, Biology	2	6
Biology	2	10
Mathematics	2	..
Mathematics, French or German	1	14
Mathematics, Physics, Biology, Modern Language	1	10
Mathematics, Physics, Botany, Zoölogy	1	8
Mathematics, Physics, Biology, German, Psychology	1	6
Mathematics, Physics, Biology, Geology	1	6
Physics, Physiology	1	6
Physics, Biology, Mineralogy, Geology	1	6
Mathematics, Physics, Bacteriology	1	..
Physical Science	1	..
French, German	1	..
Biological Science, Geology	1	..
No additional stated	21	
TOTAL	80	

If we consider the frequency with which an allied subject is required, it is learned in Figures 2A and 2B that the order is physics, mathematics, biology, French, German, etc. The specific requirement of any one subject (Figure 2A) varies in various colleges, *e. g.*, mathematics must be taken for periods ranging from one year to three and one-half years.

In Figure 2B the third bar may be considered astounding to some. We must bear in mind that many women's colleges belong to the class of liberal arts colleges where subjects are recommended rather than required. The bar "Min. in Sci." should be read "Minor in Science"—about twelve hours of allied science.

A brighter picture of evidence that women's colleges are aware of the knowledge of allied subjects is found in Table 10 which, like Table 9, is self-explanatory. Again the frequency with which the subjects are recommended

TABLE 10

ADDITIONAL COURSES RECOMMENDED FOR MAJORS

Course	*No. of Colleges*	*Average Units of Credit*
Biology, Mathematics, Physics, French, German	11	9
Biology, Mathematics, French, German	5	10
Biology, Mathematics, Physics	5	9
French, German	4	12
Mathematics, Physics, French, German	3	17
Biology, Mathematics, Physics, German	3	8
	1	..
German	2	..
Biology, Mathematics, Physics, French, German, Bacteriology, Home Economics	1	7
Botany, Zoölogy, Bacteriology, Physics, French, German	1	6
Biology, Physics, French, German	1	..
Biology, Physics, Mathematics, German, Home Economics	1	..
Biology, Physics, Mathematics, French, German, Bacteriology, Anatomy, Physiology	1	7
Botany, Zoölogy, Mathematics, Physics, French, German	1	6
Biology	1	6
Biology, Physics, Bacteriology, Genetics, Botany	1	10
Biology, Mathematics, Physics, Bacteriology	1	4
Biology, French, German	1	..
Physics, French, German	1	..
Bacteriology Botany, Zoölogy, Mathematics, Physics, Astronomy, Home Economics, French, German	1	5
Mathematics, Physics, Bacteriology	1	..
Bacteriology, Botany, Zoölogy, Mathematics, Physics, Geology	1	9
Bacteriology, Advanced Bacteriology, General Physiology, Zoölogy, Mathematics, Physics, Mineralogy	1	6
Physics, German	1	8
Mathematics, Physics	1	8
Mathematics, French, German	1	6
Mathematics, French, German, Bacteriology, Histology, Anatomy, Physiology	1	8
French	1	13
Bacteriology, Anatomy, Physiology	1	5
Home Economics	1	6
Astronomy	1	12
No special courses	25	
TOTAL	82	

is found in Figure 3. A large number of colleges recommend two years of German, two years of mathematics, two years of French, a year of physics, a year of biology, and various semesters of other subjects depending upon the interest of the student.

ENROLMENT IN CHEMISTRY COURSES

The enrolment of the colleges included in this study varied from sixty to six thousand six hundred thirty students. No discrimination was made against small or large institutions. All are included on the same basis.

To ascertain the interest shown in chemistry, the general chemistry course was chosen and the percentage of the total student body who were enrolled therein in the school year 1934-35 was plotted as a bar for each college in Figure 4. Each college in turn is indicated by a code number, which was given arbitrarily to that institution early in the survey and has no significance of any sort. This figure shows that the percentage of enrolment in general chemistry ranges from about four per cent. to fifty-nine per cent., with an average between ten and

fifteen per cent. To be exact, 4843 students of the studied eighty colleges, or 11.6 per cent., enrolled in this course.

Because of the tendency of colleges to divide the four years' work into a lower and an upper division, only

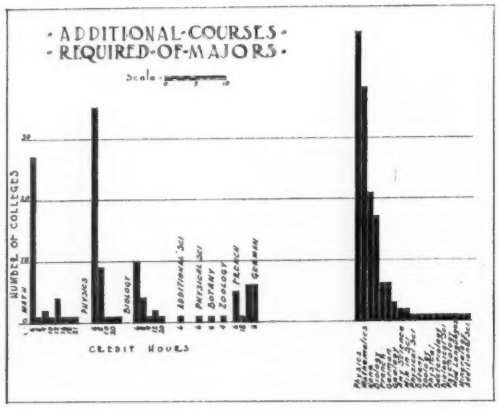

FIGURE 2A FIGURE 2B

students in the upper division, juniors and seniors, were considered majors. There were six hundred seventy-eight junior and senior majors in 1934–35, or 1.64 per cent. of the year's total enrolment. That the percent-

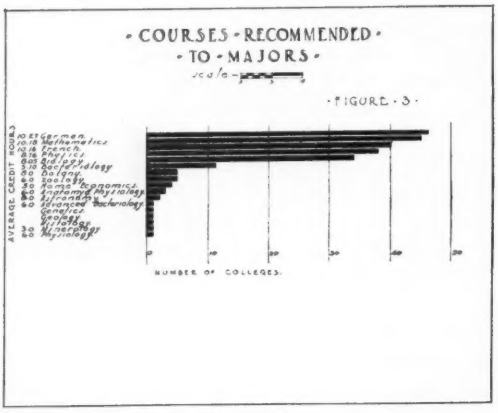

FIGURE 3

age of juniors and seniors majoring in chemistry varies at different colleges is evident in Figure 5. Here the numbers of majors are indicated in black bars, while the enrolment of the corresponding colleges is unshaded, beginning at zero each time. Some of the smaller institutions have as many majors as larger ones. These figures cannot be taken as absolute measures because the number of majors in any one college will vary from year to year. But the number is less than ten on the average.

A better means of showing the exact percentages of majors is found in Figure 6. The percentage of juniors is in black and the percentage of seniors is unshaded and above the black. The upper end of the bar indicates the total percentage of majoring students in the various colleges. The highest percentage is 5.9, with an average, as stated before, of 1.64 per cent. for both juniors and seniors. Assuming the same number of juniors as seniors, there would be 0.82 per cent. (about one in one hundred twenty) of each in an average student body.

As is to be expected, a number of the majors continue their work in graduate school, but that number is small. In order to get average figures, each institution was asked how many of its graduates attended graduate departments in chemistry between 1930 and 1935, and, also, how many of its graduates received advanced degrees in that same period. It was learned that two hundred eighty-one women's college majors did graduate work and one hundred forty received graduate degrees in that period. That means that 0.13 per cent. of the enrolment per one year (or about one student in eight hundred); or 1.16 per cent. of those taking general chemistry; or 16.95 per cent. of the chemistry majors of any one year do graduate work in chemistry.

TABLE 11

COLLEGES WHICH RETURNED QUESTIONNAIRES

1. Adelphi College
2. Agnes Scott College
3. Barnard College*
4. Baylor College
5. Beaver College
6. Belhaven College
7. Brenau College
8. Bryn Mawr College
9. Catholic Sisters College*
10. Cedar Crest College
11. Coker College
12. College of the Incarnate Word
13. College of Mount Saint Vincent
14. College of Notre Dame of Maryland
15. College of Saint Catherine
16. College of Saint Elizabeth
17. College of Saint Mary-of-the-Wasatch
18. College of Saint Teresa
19. Connecticut College for Women
20. Duke University Woman's College*
21. Elmira College
22. Flora Stone Mather College*
23. Florida State College for Women
24. Fontbonne College*
25. Georgia State College for Women
26. Greensboro College
27. Greenville Woman's College*
28. Hollins College
29. Hood College
30. Hunter College
31. Jackson College for Women*
32. Judson College
33. Keuka College
34. La Grange College
35. Lake Erie College
36. Lander College
37. Lindenwood College
38. Margaret Morrison College*
39. Mary Baldwin College
40. Marylhurst College
41. Mary Manse College
42. Maryville College
43. MacMurray College for Women
44. Meredith College
45. Mills College
46. Milwaukee Downer College
47. Mount Holyoke College
48. Mount Mercy College
49. Mount Saint Joseph's College
50. Nazareth College
51. H. Sophie Newcomb Memorial College
52. New Jersey College for Women*
53. Notre Dame College
54. Oklahoma College for Women
55. Pennsylvania College for Women
56. Pembroke College*
57. Queens-Chicora College
58. Radcliffe College*
59. Rockford College
60. Rosary College
61. Rosemont College
62. Saint Mary's College
63. Saint Mary's-of-the-Woods College
64. Salem College
65. Simmons College
66. Skidmore College
67. Smith College
68. Sweet Briar College
69. Tennessee College
70. Texas State College for Women
71. Texas Woman's College
72. The College of Liberal Arts for Women, University of Pennsylvania*
73. Vassar College
74. Wellesley College
75. Wells College
76. Wesleyan College
77. Westhampton College*
78. Wheaton College
79. William Smith College
80. Wilson College
81. Woman's College of the University of North Carolina*

* Colleges affiliated with universities.

Of the one hundred forty who received degrees, thirty had worked for the Ph.D. degree; eleven for the M.D. degree; and ninety-nine for either the M.A. or M.S. degree.

CHEMISTRY FACULTY

The fitness of a college to grant degrees depends in part on the faculty. In turn the value of a faculty member may be measured in terms of his personality, teaching ability, and training. It is practically impossible to evaluate the two qualities first mentioned. The third, training, has been chosen as the means of judging two hundred seventy-three faculty members, including assistant instructors, in the various eighty women's colleges mentioned above. Incidentally, that number of faculty will average one faculty member for every one hundred fifty-two college students.

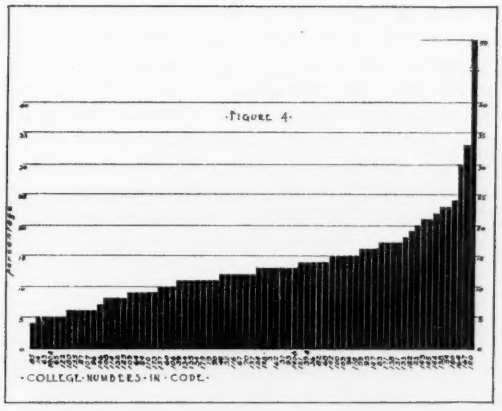

FIGURE 4

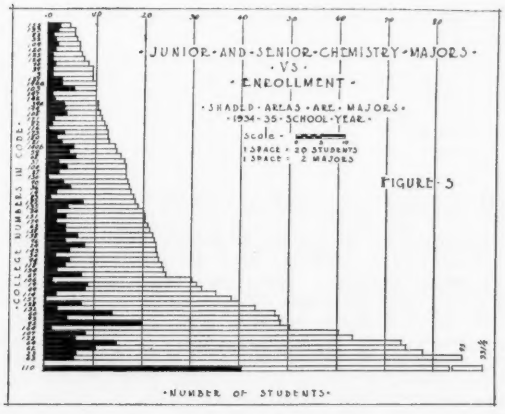

FIGURE 5

The faculty from the professorial rank on down were graphed in Figure 7 according to their graduate training. It is to be noted that professors, associate professors, assistant professors, and instructors are predominantly persons with the Ph.D. degree. Fewer of them have the M.A. or M.S. degree, and a very few have the bachelor's degree. On going down the ranks one finds relatively more teachers with the master's degree and fewer with the doctorate.

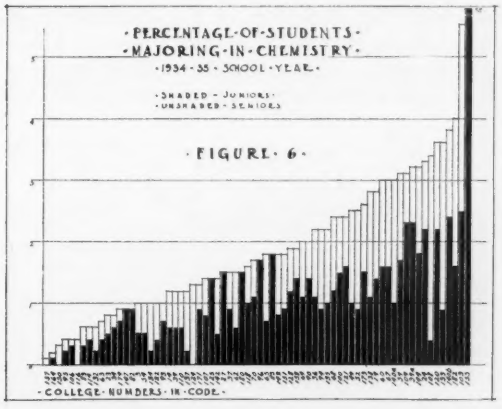

FIGURE 6

A count of the number of members in each rank shows that there are fewer associate professors than assistant professors and fewer of the latter than instructors. That order is presumably correct from an administrative standpoint.

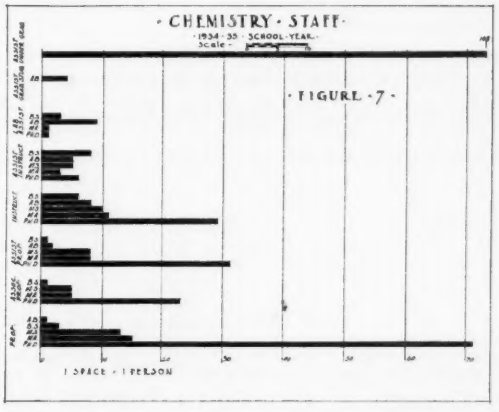

FIGURE 7

The large number of assistants who are undergraduates is not surprising, because it is common practice in both men's and women's colleges to use college students in the laboratories.

Even though, as will be seen later, their teaching hours are rather long, the faculty are also interested in

research. Of the above-mentioned two hundred seventy-three faculty members, one hundred nine or 39.9 per cent. conduct research.

It was considered a matter of interest to try to correlate the number of faculty members at various institutions with the student body, the chemistry courses offered, and the required chemistry courses. This was done in Figure 8. Curve 1 indicates the increasing enrolment from left to right. Curve 4 shows the change

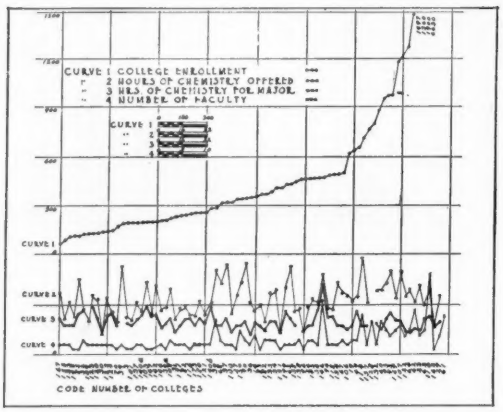

FIGURE 8

in chemistry faculty numbers with the increase of enrolment. There is an increase in faculty with increased student body but not a close relationship. Some smaller institutions have more faculty members than much larger ones.

On comparing Curve 2, chemistry courses offered, with Curve 4, faculty, one finds rough agreement. Where there are inflections on one curve, there generally are on the other. However, the colleges which offer the largest number of chemistry courses are not necessarily those which have the largest faculty. On the average each faculty member teaches the equivalent of 14.3 credit units per semester, if all the courses which are offered are given.

An examination of Curves 2 and 3 shows the relationship between the total credit hours of chemistry offered as compared to the number of credit hours for an A.B. degree with a major in chemistry. It will be noted that some colleges give very little chemistry over and above that which is required, while others give a large number of hours and require only a small part of it. The poor agreement in contour of the curves may be due to a requirement on the chemistry departments to give courses requested by other departments.

In averaging the points on both curves one finds that seventy per cent. more courses of chemistry are given than are required.

In Figure 8 the faculty numbers contain only those faculty members of the rank of instructor or above. Curve 1 has its origin two large spaces above the origin of Curves 2, 3, and 4.

* * *

The author wishes to express his sincere appreciation to the chairmen of the chemistry departments of the various women's colleges and of the universities for their kind coöperation in making the survey possible.

SUMMARY

1. Chemistry has a distinct place in the curricula of women's colleges.

2. The colleges in turn offer, even though they may not require, ample courses to train the students thoroughly for professional, as well as graduate, work.

3. The courses are well chosen to take care of the particular demands for women chemists.

4. The faculties are thoroughly trained and active in their field.

5. The cost of education as gaged by fees is not excessive.

COMMITTEES OF THE DIVISION OF CHEMICAL EDUCATION

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Examinations and Tests: (Estd. 1931) O. M. Smith, Oklahoma A. & M. College, Stillwater, Oklahoma, *Chairman;* R. D. Reed, F. B. Wade, E. W. Phelan, R. E. Kirk, B. C. Hendricks.

Committee to Study the Boy Scout Merit Badge in Chemistry: (Estd. 1935) R. A. Baker, College of the City of New York, *Chairman;* E. Q. Adams, H. S. Bailey, F. E. Brown, G. M. Browne, C. D. Carpenter, T. S. Chapman, W. F. Henderson, W. S. Lapp, W. F. Rudd, R. I. Rush, H. A. Schuette, P. Serex, F. D. Tuemmler.

New Type College Board Examinations: (Estd. 1936) G. H. Bruce, Horace Mann School, New York City, *Chairman;* S. R. Brinkley, Mary Ford, Katharine Weaver, R. D. Reed.

Nomenclature of Acids, Bases, and Salts: (Estd. 1936) H. N. Alyea, Princeton University, Princeton, New Jersey, *Chairman;* L. P. Hammett, J. H. Hildebrand, W. C. Johnson, E. A. Wildman.

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ABSTRACTS

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KEEPING UP WITH CHEMISTRY

Chemical insecticides. Anon. *Ind. Eng. Chem., News Edition*, **15**, 61 (1937).—Report of U. S. Department of Agriculture states that phenothiazone is the most promising of the department's "new" insecticides. Its principal deterrent is the effect on the skin of the persons handling it. Tests are being carried out to determine new ways of spraying or dusting with this compound. Nicotine with bentonite, nicotine sulfate in oil emulsions, and cryolite are being investigated. Cryolite is poisonous and the removal from fruit presents difficulties.
A. A. V.

Optical lenses moulded from plastic material. Anon. *Nature*, **139**, 336 (Feb. 20, 1937).—Optical lenses molded from plastic materials were recently exhibited in London. The inventor of this British process is Mr. A. Kingston. Since the refracting surfaces are produced by molding, the tedious and expensive operation of grinding can be avoided. The plastic material in the lenses bears the trade name of "Perspex". It has about half the density of glass and is practically unbreakable. Its refractive index is approximately the same as that of crown glass.
M. E. W.

Fluorescence of the bivalent rare earths. K. Przibram. *Nature*, **139**, 329 (Feb. 20, 1937).—According to Dr. Przibram, ". . . the blue fluorescence shown by fluorites is due to bivalent europium produced through reduction of traces of trivalent europium by radium rays . . . a yellow-green band shown by some fluorites at low temperatures can be ascribed to bivalent ytterbium . . . a red fluorescence band . . . is due to bivalent samarium . . . " A rare earth preparation from the Auergesellschaft in Berlin, said to contain ninety-three per cent. of thulium oxide Tu_2O_3, was added to calcium sulfate and exposed first to radium rays and then to filtered ultraviolet light. At low temperatures a red fluorescence appeared, which became very brilliant at the temperature of liquid air.
M. E. W.

Retrospects. *Ind. Eng. Chem.*, **29**, 4–8 (Jan., 1937).—A summary of the important developments in chemistry in 1936 is given. In the industrial field a new variety of glass of the Pyrex type was developed which resists heat sufficiently to be used in frying pans in direct contact with flame. A process for recovery of Mn by the electrolysis of a solution of Mn in SO_2 was reported by the Bureau of Mines, suitable for treatment of low Mn ores. A new method of dehydrating alcohol by the use of sodium acetate and other salts was put into operation. Large scale investigations into the suitability of alcohol as a blend in motor fuels were carried out.

In physical chemistry a new method of taking motion pictures through the spectroscope was developed, greatly increasing its use in the detection of traces of materials. The method of producing polarizing plates by the production of tiny crystals on an elastic medium, on which they are then oriented by stretching the medium, was developed. This layer can be cemented between glass plates. The method of producing a large thin crystal on glass, protected by cementing another glass plate over it, was also used. Iodine substitution products of the alkaloids are used. Be atoms were produced from Li by bombardment with protons. By deuteron bombardment tiny amounts of Pt were changed into Au; Na was changed into Mg by means of neutrons. Artificial radioactivity has been imparted to more than forty elements.

In medical chemistry important developments were announced in the study of tubercle bacilli, virus diseases in plants, carbon monoxide poisoning, and protamine insulin. The synthesis of vitamin B_1 was accomplished, and it is claimed that it can be produced more cheaply than it can be extracted from natural sources. Theelin, one of the two hormones responsible for female characteristics, was synthesized. Porphin, the common chemical ancestor of hemoglobin and chlorophyll, was also synthesized. Traces of Co were found to be important in preventing certain types of anemia. Iodocholeate, a new preparation of iodine of high germicidal value, was introduced. Totaquine was developed as a substitute for quinine. Synthetic resins are being used in the manufacture of new types of contact lenses to replace eyeglasses. The actual lens is made of glass and fitted in a shield individually molded to the wearer's eyeball to be placed beneath the eyelids. The new dental anesthetic (2 parts sulfuric ether, 1 part ethyl alcohol, and 1.25 parts thymol by weight) was found effective in many cases.

The use of iodine in a new method of finger-printing was introduced. Plant hormones which induce growth in a few days when rubbed on plants or cause the formation of roots at unusual places were reported. Sixteen chemicals and plant extracts were found to have this property. Investigation of the stratosphere shows there is no change in the ratio of N_2 to O_2 at a height of about fourteen miles.
D. C. L.

Spring tonic. Anon. *Ind. Bull. of Arthur D. Little, Inc.*, **121**, 3 (Feb., 1937).—There is a flurry of excitement over the discovery that plant growth and plant development may be controlled by certain chemicals. The farmer's medicine chest will soon be enlarged to include some of these plant tonics. This mastery over plants has come from the study of at least three puzzling findings. The botanist, Sachs, more than fifty years ago conceived the idea that plants have chemical control over their flowering and fruiting processes, but he could not determine what organ produced the chemical. Darwin also believed that something chemical involved the plant response to light. It was a generation later that Boysen, Jensen, and others found that a strange chemical was produced in the growing tip. This chemical today is known as "Auxine." The second finding was the presence of plant-stimulating materials in animal manures that were absent from purely inorganic fertilizers. Zimmerman and his co-workers followed with the effect of minute amounts of illuminating gas on greenhouse soil. There are several chemicals now known to exercise control over plants, including several gases, such as ethylene and propylene, and carbon monoxide. The liquid ethylene chlorhydrin may be used as a dip for potato cuttings. The most interesting solids are those in dolebutyric acid and its relatives.
G. O.

Aërogel. Anon. *Ind. Bull. of Arthur D. Little, Inc.*, **121**, 4 (Feb., 1937).—We are more or less familiar with the jellies of agar agar or gelatin. Several years ago, Professor Kistler of the University of Illinois devised a process whereby the water of a jelly could be displaced by a liquid such as alcohol, leaving jelly in its original volume; and then by converting the alcohol to a gas, a pithlike form which is called aërogel can be secured, not only from jellies noted above, but also from oxide gels of silicon, iron, nickel, tin, titanium, aluminum, and other elements. The aërogel of silica, "Santocel," is now available for use. It comes as a powdery mass, soft and compressible. If kept dry, it is a good insulator, and has been suggested for thermos bottles, household refrigerators, and ice-cream cabinets. Aërogel mixes rapidly with pigments which may find practical application in paints and lacquers. It has been suggested as a suspending aid for printing inks. Certain grades are said to adsorb as much as eighty per cent. of their volume of water without apparent wetness.
G. O.

From waste to wealth. F. Thore. *Sci. News Letter*, **31**, 122–4 (Feb. 20, 1937)—Lignin, for so long an undesirable by-product of the treatment of wood fiber for its cellulose, is here presented as a promising competitor with other plastics for a place in the economic sun. Some of its properties pointing to such use are high electrical resistivity, water and acid resistance,

and poor heat conductivity. The product from lignin waste is improved by the addition of from six to eight per cent. each of aniline and furfural. Not of least importance is the low cost of this material, or its abundance. It is estimated that millions of tons of it are now dumped into our streams each year. Back of that are further millions of tons of it in waste woods.

B. C. H.

The molecular structure of cellulose and starch. G. F. DAVIDSON AND W. A. RICHARDSON. *Science Progress*, **31**, 68–77 (July, 1936).—On account of their great biological and industrial importance, cellulose and starch have long engaged the attention of chemists, and numerous structural formulas have been assigned to them. Because of their great importance to the textile industry, the changes in the chemical and physical properties of cellulose have often been studied, and, in particular, they have formed the subject of researches in the laboratories of the British Cotton Industry Research Association. A number of relations between various properties have been revealed which have proved invaluable in the control of the processing of cotton, and in the assessment of the degree of chemical modification of cotton cellulose, but which are extremely difficult to interpret in terms of any of the older theories of the structure of cellulose.

The action of acids on cellulose (formation of so-called "hydrocellulose") is marked by an increase in reducing power, a fall in tensile strength, and in viscosity in cuprammonium solution, and an increase in solubility in cold sodium hydroxide solution. It is found that the inter-relations of these properties are always the same, whatever the conditions of the acid treatment. According to the theory, the action of acids consists in the hydrolysis of glucosidic linkages in the chain-molecules, with the production of shorter chains and liberation of reducing groups. The viscosity and tensile strength are related to chain-length, and the solubility is determined by the proportion of the material that consists of chain-molecules below a certain length; consequently these three properties are all functions of the chain-length frequency distribution, and hence show definite relations to the reducing power and to each other.

The behavior of cellulose toward oxidizing agents is much more complicated, for the chemical properties of the products ("oxycelluloses") corresponding to a given oxygen consumption depend on the oxidizing agent employed. The oxidation process always leads to a loss of strength, a fall in viscosity, and an increase in solubility, showing that chain-molecules are broken. Although in any given series of oxycelluloses these properties show definite relations to each other and to the chemical properties, the relations vary from one type to another.

The chemical modification of starch has been much less extensively studied than that of cellulose, but it has been shown that, in accordance with the molecular chain theory, the action of acid results in an increase in reducing power and solubility, and a fall in viscosity; the so-called "soluble" starches differ from natural starch in having a lower average chain-length. It is probable that a more systematic investigation of the chemically modified starches would be of great value in helping to clear up such controversial questions as the relation of amylose and amylopectin to each other and the nature of the retrogradation process.

R. K. C.

HISTORICAL AND BIOGRAPHICAL

Chemistry a century ago. Benzoic acid and benzene. ANON. *Nature*, **139**, 165 (Jan. 23, 1937).—The following is quoted from the Athenaeum, "At a meeting of the Medico-Botanical Society held on January 25, 1837, Mr. Everett made some observations on the essential oil of almonds, the result of the examination of which by different continental chemists led to the hope that the mathematical accuracy impressed upon inorganic compounds would soon be developed in organic compounds. In the analysis of almonds, a substance called amygdaline was produced. From this substance the German chemists have produced a liquid hydruet of benzoin, which, by contact of atmospheric air, produces benzoic acid. With this discovery, M. Berzelius was so pleased as to suggest to MM. Dumas and Leveque (to whom the scientific world is indebted for this information) to give it a name signifying 'Dawn of Day' or 'Orb of Day,' illustrative of the new era which it opened in organic chemistry. M. Mitscherlich, of Berlin, has also, by the distillation of benzoic acid with quicklime, obtained an oily fluid identical with that procured in the condensation of oil gas, and described by Faraday as a liquid bi-carburetted hydrogen." M. E. W.

Sir Joseph Banks's London house. ANON. *Nature*, **139**, 280 (Feb. 13, 1937).—Sir Joseph Banks's home at 32 Soho Square, London, is to be removed. The tablet placed on it in 1911 will be preserved. A plan and description of it were published in *Country Life* for September 27, 1913. Sir Joseph lived in this home from 1777 until his death in 1820, and his famous collections were housed there. He bequeathed them to Robert Brown, who transferred them to the British Museum.

M. E. W.

Prof. Edward Turner (1798–1837). ANON. *Nature*, **139**, 298 (Feb. 13, 1937).—On February 13, 1837, Edward Turner, professor of chemistry at University College, London, died at the age of thirty-nine years. He was a graduate of the University of Edinburgh and studied under Stromeyer at Göttingen. Sir Edward Thorpe said of him, "He is especially to be remembered for his determination of the atomic weights of lead, chlorine, silver, barium, mercury, nitrogen, and sulfur; they were the first atomic weights to be measured by a British chemist and are worthy to be ranked with those of Berzelius." Turner's work led to the rejection of Prout's hypothesis that all equivalents are simple multiples of the equivalent of hydrogen. Stas arrived at the same conclusion half a century later. A marble bust of Turner was placed in University College by his pupils. He was succeeded by Thomas Graham. M. E. W.

The origin of Fahrenheit's thermometric scale. J. NEWTON FRIEND. *Nature*, **139**, 395–8 (Mar. 6, 1937).—The bicentenary of the death of Daniel Gabriel Fahrenheit (1686–1736) has recently been observed. Many incorrect statements regarding the fixed points on his thermometer appear in the literature. A recently discovered letter of Fahrenheit to Boerhaave, which has been translated from Dutch into German by Ernst Cohen and W. A. T. Cohen-De Meester, shows that Fahrenheit "did not choose 32° and 212° for the freezing and boiling points of water; they were mere incidents on his scale, which was . . . based upon two fixed points, namely, a zero obtained by immersing his thermometer in a mixture of ice and sal ammoniac, and an upper point at blood heat, which Fahrenheit took as 96°."

Dr. Friend gives a résumé of the early history of thermometry and explains why Fahrenheit chose these fixed points in preference to the freezing and boiling points of water and why the upper fixed point was designated as 96°. Most of Fahrenheit's thermometers were intended for meteorological purposes. Dr. Friend believes that Fahrenheit deliberately chose as his zero the lowest temperature then available so that all meteorological readings would be positive. Fahrenheit probably considered the boiling point of water as too high for the upper fixed point for meteorological purposes. He based his scale on that of Ole Roemer, which was divided into $22^1/_2$ parts, beginning at 0. In iced water the reading was $7^1/_2$; at blood heat, $22^1/_2$. Fahrenheit at first divided each of Roemer's degrees into four parts, which gave 90° as blood temperature. Later he found it more convenient to call blood temperature 96° instead of 90°. Thus the melting point of ice became 32° instead of 30° ($7^1/_2$ Roemer degrees divided into quarters). Fahrenheit probably regarded 96° as more convenient than 90° for blood temperature because it is divisible not only by three but by multiples of two. "The decimal system was not then in general use in scientific work . . . Although we retain a Fahrenheit scale today, it is not quite the same as that which Fahrenheit used. The lower and upper fixed points adopted are those deliberately rejected by Fahrenheit, ice being taken to melt at 32° and water to boil under standard conditions at 212°."

M. E. W.

TEACHING OBJECTIVES, METHODS, AND SUGGESTIONS

Visual instruction project in laboratory chemistry. J. M. LEVELLE. *Educ. Screen*, **16**, 39–40 (Feb., 1937).—Proper laboratory technic is the major objective of the project described in this paper. Pupils and teacher together seek to contrast correct laboratory technics with incorrect ones by photographing both and preparing lantern slides from the negatives for the benefit of the whole class. Twenty such subjects are described. Suggestions as to proper lighting and grouping for effective results are given. B. C. H.

Evaluating chemistry instruction. F. P. FRUTCHEY. *Educ. Research Bull.*, **16**, 1–6 (Jan. 13, 1937).—After listing some fourteen objectives of chemical instruction the author points out the limitations of pencil-and-paper tests in evaluating achievements of some of the objectives enumerated. "A comprehensive evaluation program calls for a variety of methods for collecting evidence of growth." The correlations of success in information tests with tests of ability to draw inferences or application of principles are low. A single score is not an adequate index of a comprehensive picture of a student's growth. Uses, four in number, are advanced for making attempts to evaluate the outcomes of chemical instruction. The reader is told how to clarify objectives with the purpose of measuring the extent of their achievement by examinations. The usefulness of anecdotal records in appraising a student's progress toward habitual demands for evidence before decisions are made is suggested. Indirect evidence of student success in attaining the objectives of chemistry is offered as a means of improving the adequacy of the sampling. However, such indirect test forms are not considered acceptable until their high correlations with the more direct form are established. Illustrations of methods used in securing such correlations are presented. B. C. H.

GENERAL

Our basic standards of measurement. J. E. SEARS. *Science Progress*, **31**, 209–35 (Oct., 1936).—The adoption and use of a uniform system of weights and measures for purposes of trade has been recognized from the earliest times. At present, it may be fairly said that there are only two basic systems of weight and measure of importance in the whole civilized world—the British Imperial System, and the International Metric System. The need for uniform standards of measurements for scientific purposes is a more recent development; but the degree of precision required in this connection is greater than is ordinarily necessary for purposes of trade—*i. e.*, for the buying and selling of goods—though the accuracy of measurement demanded for certain purposes by industry is such as to tax the metrologist to the limit of even his present-day resources.

There are four ways in which we can define the fundamental units of any system, by reference either to arbitrary material standards, to the properties of specified substances, to natural phenomena, or to physical constants. The present units of length and mass in both the British and Metric Systems are defined by reference to arbitrary material standards, but the unit of time is defined by reference to a natural phenomenon, the time taken by the earth to rotate upon its axis. The kilogram was originally defined as the mass of a cubic decimeter of pure distilled water at its temperature of maximum density, but this definition was subsequently abandoned in favor of the arbitrary material standard (the Kilogramme des Archives) which was constructed in the first instance merely to serve as the physical embodiment of the mass so defined. There are, of course, many other units which are used as standards, especially electrical units.

The following table summarizes the nature of the reference standards upon which our fundamental units of measurement depend, with the accuracy attainable in each case.

Units of	*Basic Reference Standard*	*Character of Reference*	*Accuracy Realized*
Length	Imperial St'd. Yd.	Arbitrary Material	$\pm$ 5 parts in 10^7
	International Prototype Metre Wave-length of light	Arbitrary Material	$\pm$ 2 parts in 10^9
		Natural Phenomenon	$\pm$ 2 parts in 10^8
Mass	Imperial Standard Pound	Arbitrary Material	$\pm$ 1 part in 10^8
	International Prototype Kilogramme	Arbitrary Material	(accuracy of weighings)
Time	Second	Natural Phenomenon	$\pm$ 1 part in 10^7 (frequency)
Electrical quantities	Electro-magnetic permeability of space	Physical constant	$\pm$ 2 parts in 10^4 (ampere or ohm)

As to the constancy of these units we can say with regard to the three alternative standards of length that the two material standards may now be regarded as permanently stable within the limits of accuracy to which they can be measured; the wave-length of light is also reproducible within its corresponding limit. The standard kilogram is probably similarly stable and, assuming this to be the case, any future change in the present standard pound is not likely to exceed 15 parts in 10^8 as a maximum. It is however, recommended in the Board of Trade Report on the Decennial Comparisons of 1933 that steps should be taken with a view to establishing an improved standard for the pound.

As regards the second of time, improved methods of measurements are even now being developed through which the accuracy of measurement of this unit may be increased in the near future to at least one part in 10^8. The constancy of this unit depends upon that of the natural phenomenon from which it is derived. Its rate of change is probably of the order of one part in 10^7 per century. Improved methods of measurement will enable us in the future to determine this with greater accuracy and, if necessary, to re-define the unit on a more constant basis.

Finally, regarding the electrical quantities, we note that in effect, the fourth "unit" is the only one based on a natural constant. In this way, its absolute long-time period invariability may be regarded as assured. But it is to be noted that practical measurements based on this "unit" reach a much lower standard of precision than those based on material standards, whether arbitrary or natural, with the result that the actual standards of electrical quantity are of a relatively low order of precision. It is not impossible that the adoption of a material standard, say, of the ohm or henry, in preference to the permeability of space, as the starting-point for the system of electrical quantities, would lead temporarily to a higher degree of precision. But such a standard would suffer from a disadvantage exactly comparable with that attaching to the material standard of mass—namely, that there would be no means of assessing definitely the absolute stability of the unit over a long period. It will be a matter of considerable interest to watch whether the precision of "absolute" measurements, or the stability of material electrical standards makes the more rapid progress. The accuracy hitherto realized in measurements made by direct reference to physical constants, such, for example, as the velocity of light in vacuo, falls so far short of that attainable by other means that the theoretical advantage of an ideally invariable and logical basis has for the present, at any rate, to be foregone. R. K. C.

Versatility in dyestuffs equipment. J. A. LEE. *Chem. & Met. Eng.*, **44**, 124–7 (Mar., 1937).—The American dyestuffs industry has made great strides since the World War. At present there are several very large plants in this country producing immense quantities of colors for the purpose of dyeing cotton, wool, silk, rayon, and other fibers, and such other materials as paper, rubber, and synthetic resins.

While many of the dyes produced are standard and are consumed in large quantities, many fluctuate in demand from year to year, largely due to changes in fashion. The producer must be prepared to meet this demand and to do so economically. His equipment must be extremely flexible. That is, it must be able to resist acids and alkalies, high and low pressures, high and low temperatures. Above all, the equipment must be easily cleaned of all traces of dyestuffs previously processed so as not to affect the next batch. The modern dyestuff manufacturers take all of these matters into consideration in designing their plants. J. W. H.

RECENT BOOKS

REAGENT CHEMICALS AND STANDARDS, with Methods of Assaying and Testing Them; Also the Preparation and Standardization of Volumetric Solutions and Extensive Tables of Equivalents. *Joseph Rosin*, Chief Chemist and Chemical Director, Merck and Company, Inc. D. Van Nostrand Company, Inc., New York City, 1937. ix + 530 pp. 15 × 23 cm. $6.00 net.

The author has brought to the preparation of this reference book on standards and specifications the experience of more than twenty-five years in directing the production of reagent chemicals. During this time he has also served as a member of the Committee on Analytical Reagents of the American Chemical Society and the Revision Committee of the U. S. Pharmacopoeia.

The scope of this book is indicated in the foreword by N. H. Furman.

"This volume is based on the general plan of Murray's 'Standards and Tests for Reagent Chemicals,' but a careful examination of its contents will convince the reader that practically every set of specifications, for the maximum limits of impurities and the methods of detecting and estimating them, has been critically studied and revised to conform with more recent analytical procedures and the present established standards. These standards are, of necessity, based on the one hand upon the requirements of purity for the various applications of each substance, and on the other hand upon the present state of the difficult art of manufacture and purification of chemical substances. A comparison of the standards of the present volume with those of the book which it replaces gives clear evidence of the rapid progress that has been attained in the production of purer and more universally satisfactory materials, and in this progress the author of the book has had a very significant share."

The first eight pages of the book specify the purity, concentration, and preparation of the test reagents. Pages 9–473 list the reagent chemicals and standards in alphabetical order. On an average, about one page is devoted to each substance. The formula and molecular weight of the compound is followed by a brief statement of its important chemical characteristics and physical properties, such as melting point, boiling point, and density. Then there follows a list of the maximum allowable impurities and a brief description of the methods used to determine them. Most of the tests for chloride, sulfate, heavy metals, iron, etc., are quantitative. It is not sufficient, however, to know how much impurity is present; the percentage purity of the reagent itself is often more significant. The author therefore, gives a method of assaying or determining quantitatively the active constituents of nearly seventy per cent. of the reagent chemicals. This he considers "one of the most effective ways of checking the quality of a chemical." Some of these assays are based upon a determination of physical properties, but most depend upon acid-base, oxidation-reduction, and precipitation titrations.

The preparation and standardization of the volumetric solutions is described in ten pages, after which twenty-six pages are devoted to a tabulation of the weights of different substances equivalent to 1 cc. of the acids, bases, oxidizing, reducing, and other reagents used in the assays. These tables include values for many other substances, besides those analytical reagents listed in the book.

The last seven pages of the text are devoted to buffer solutions, indicators, and colorimetric determination of pH, which has many applications in the reagent tests. An adequate index of eight pages concludes the book.

This volume is well printed on good paper and securely bound. It should prove a useful reference book in any laboratory where reagent chemicals are employed and careful analytical or testing work is carried out. It is also a storehouse of analytical information and illustrates the more and more precise and convenient analytical methods developed by many workers, tested and improved by the author from his own wide experience.

FRANK T. GUCKER, JR.

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APPLIED CHEMISTRY FOR ENGINEERS. *A. F. H. Ward*, M.A., Ph.D. (Cantab.), B.Sc. (Lond.), A. I. C., Assistant Lecturer in Physical Chemistry in the College of Technology and the University, Manchester. Longmans, Green and Co., New York City, 1936. xi + 127 pp. 6 figs. 12 × 18 cm. $1.75.

Here is a splendid little book which reminds us that the recent slogan "Buy British" may be wise, if not patriotic.

The preface states that the book "is intended to provide a practical course in applied chemistry for students of mechanical, municipal, or electrical engineering in technical colleges and universities. It will also be useful for students of pure chemistry needing an introduction to applied chemistry."

The book consists chiefly of concise directions for experiments but also contains excellent summaries and discussions of methods. It is made up as follows: Part I, Water Examination, consisting of twenty-two experiments; Part II, Boiler-Water Treatment, nine experiments; Part III, Corrosion, twenty-five experiments; Part IV, Coal and Oil, twenty-one experiments.

Parts II and III seem to be most complete in their treatment of Boiler-Water and Corrosion. Part IV is somewhat meager in its treatment of coal analysis.

Such a text accompanied by suitable lectures would afford an excellent course for engineers. More of our colleges will be training students in these industrial applications. Dr. Ward has included sufficient theoretical matter at most points to show the physico-chemical explanations for methods which too often are presented inadequately.

There are a few points which differ from American practice. Hardness is expressed in parts per 100,000. Potentials of metals in solutions of their ions are expressed with a negative sign for the more active metals. This, of course, has always been a matter of disagreement, even among different authors in this country.

The book is well written and singularly free from errors. One might wish for more diagrams, or pictures, of apparatus used. Occasionally, also, mere references to source literature might be expanded profitably.

R. D. BILLINGER

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DAGUERRE-SCHRIFTEN. *Erich Stenger*, Professor of Chemistry, Technische Hochschule, Charlottenburg. The author's private press, Berlin-Charlottenburg, 1936. 18 pp. 30 figs. 22 × 30 cm. Edition limited to 150 numbered copies.

Most of the Daguerre writings described in this brochure are in Professor Stenger's private collection. François Arago announced Daguerre's discovery to the French Academy of Sciences on January 7, 1839, and described the process at a joint meeting of the Academies of Arts and Sciences on August 19th of the same year. The essential details of the process were first published by Arago in the *Comptes Rendus*, 9250–67 (1839), but the first widely circulated report of it was the brochure, "Historique et description des procédés du Daguerréotype et du Diorama," which Daguerre himself published in Paris in the same year. This contained the reports of the Chamber of Deputies for June 15, July 3, and July 30, 1839, the decree of Louis-Philippe according to which Daguerre and Nicéphore

Niépce's son, Isidore, were granted a lifelong income, the history of the daguerreotype process, the agreement with the Niépces, father and son, the accurate description of the process, the explanation of the illustrations, and a short description of the diorama, which Daguerre had invented in 1822.

This publication was promptly followed by at least twenty-one other editions in French, German, English, Spanish, Swedish, Hungarian, Italian, and Polish, all of which appeared in 1839 or 1840 under various titles, with omissions or addenda. Lerebours and the Susse brothers, for example, suggested in their edition (Paris, **1839**) that the person whose portrait was being made ought to be seated in bright sunlight behind a large pane of blue glass "to avoid fatigue and the blinking of the eyes..." and added that this would not necessitate a longer exposure. The first American edition was entitled, "Description of the Daguerreotype Process or a Summary of M. Gouraud's Public Lectures according to the principles of M. Daguerre, with a description of a provisory method for taking Human Portraits," Dutton and Wentworth's Print, Boston, **1840**, 16 pp.

Professor Stenger's rare brochure has beautiful typography, an artistic format, and clear reproductions of the title pages of many of the early Daguerre writings.

MARY ELVIRA WEEKS

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ENZYME CHEMISTRY. *Henry Tauber*, Consulting Chemist, formerly Instructor, New York Medical College and Flower Hospital. John Wiley and Sons, Inc., New York City, 1937. xii + 243 pp. 28 figs. 17 tables. 14 × 23 cm. $3.00.

The aim of the author has been to prepare a summary of recent progress in the study of enzymes. Especially valuable features of the book are: (*a*) a well-selected bibliography of the literature since 1930, cited in the discussions of each chapter, (*b*) brief statements of earlier views, followed by summaries of recent experimental findings and views, and (*c*) a well-organized Table of Contents, from which one can readily find specific material in the text. The manuscript has been carefully prepared from an earlier temporary edition, so that typographical errors are relatively scarce.

The discussion of theories pertaining to enzyme kinetics has been kept extremely brief. In the reviewer's opinion, additional material on enzyme kinetics and a more thorough development of historical background would add to the value of the book. Since these two points are well covered in earlier books, however, the present volume, with a good summary of recent work, will prove very useful.

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PROCTOR'S LEATHER CHEMISTS' POCKET-BOOK. *W. R. Atkin*, M.Sc., and *F. C. Thompson*, M.Sc. Third edition. E. and F. S. Sporr, Ltd., of London and the Chemical Publishing Co., New York City, 1937. xii + 386 pp. 29 figs. 12 × 18.5 cm. $6.00.

This book was primarily written as an aid to the chemist associated with control and analytical work of the leather industry. The book, as a whole, is excellent, since it covers almost the newest analytical methods now used by the leather chemist. The first third of the book, or first five chapters, is devoted to a discussion of the ionization of acids, bases, and salts, a thorough discussion of hydrogen-ion concentration and the latest methods of obtaining pH values. Qualitative and quantitative procedures are given for the evaluation of vegetable tanning materials. The chapter dealing with the qualitative detection is especially valuable. These chapters are well worth reading by those interested in vegetable tannin analysis. One chapter is devoted to the analysis of vegetable-tanned leather, another to the analysis of mineral-tanned leather. These chapters are well written and give the latest methods of analysis. Four chapters are devoted to oils, fats, waxes, soaps, egg yolk, and sulfonated oils. The work given on sulfonated oils would have been much improved by giving the latest methods of their evaluation. This chapter is rather incomplete. The reviewer believes that more quantitative methods should have been given—such work including the methods devised by Schindler and the Textile Association methods.

A single chapter is devoted to the physical testing of leather. The reviewer feels that insufficient space has been given to this important phase of the work and should have been expanded in a handbook of this character.

The remainder of the book covers the analysis and evaluation of finishes, the use of the microscope and its use in bacteriology.

The book is one which should be in the library of any individual interested in the analysis of leather and those chemicals which go into the fabrication of leather. Its educational value lies in the fact that it is an excellent treatise on the analytical procedure used in the leather industry and should be brought to the attention of students in organic quantitative analysis.

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THE COSMETIC FORMULARY. *H. Bennett*, F.A.I.C., Chemical Publishing Company of New York, Inc. New York City, 1937. xix + 259 pp. 15 × 23 cm. $3.75.

Patterned on the style of THE CHEMICAL FORMULARY, by the same editor, this work was published almost simultaneously with MORE FOR YOUR MONEY, by the same Mr. Bennett, recently reviewed in THIS JOURNAL (Vol. 14, No. 4, pp. 198–9).

The text comprises recipes for every type of cosmetic product used on skin and hair; also dentifrices, perfumes, and miscellaneous related semi-medical preparations. It also gives several useful tables of equivalents, common names of chemical compounds, lists of manufacturers of raw materials and equipment, reference books, etc.

The declared purpose of the book is to further the education of teachers, students, and the public on cosmetic preparations and treatments, and the recipes are alleged to serve only as starting points for the development of good products. There is a sketchy synoptic section on manufacturing technic, which a teacher, trained to use his hands, should be able to follow with fair success. The experimenter is warned not to deviate an iota from the directions given, or to substitute other ingredients for those prescribed. Basically good advice, this; but one may readily question the educational value of so many hundreds of recipes based on proprietary raw materials, when no clue is given as to the chemical nature of those listed. To this reviewer, at least, all such "advertising formulas" are just as exasperating as a problem in algebra with three or four unknown quantities.

As the movement for education on cosmetics spreads in our schools, and as more research on problems related to cosmetics is undertaken by private and public agencies, there will always be room for good handbooks on the composition and compounding of the products used in this vast industry. Such publications, however, should be edited with skill and restraint, and in the best interest of both educators and prospective manufacturers, recipes should be well tested both "on the shelf" and clinically. The author's intention here was good, but, regrettably, THE COSMETIC FORMULARY adds little to the trade literature on cosmetics.

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ORGANIC CHEMISTRY FOR MEDICAL STUDENTS. *George Barger*, Professor of Chemistry in Relation to Medicine in the University of Edinburgh. Second edition. Gurney and Jackson, London and Edinburgh, 1936. xi + 251 pp. 15 figs. 15 × 23 cm. 10/6 net.

Occasionally authors have the temerity to write textbooks in the fundamental sciences for preprofessional groups. Such a venture is always open to the tendency to give too much application and too little that is fundamental. Certainly a textbook

on general chemistry for medical students would hardly be looked upon with favor.

Premedical requirements have for many years included organic chemistry. A number of texts in this subject have been written especially for students in this profession. This book is a good combination of fundamentals of the subject and application to the field for which it was written. At frequent intervals the author introduces brief but excellent discussions of groups of organic compounds that must appeal to premedical students, for example, inhalation anesthetics, astringents, hypnotics, etc. This type of application is a distinct asset to the work and conducive to sustained interest.

The text is not full enough for a whole year of organic chemistry, and whether a semester is sufficient time to devote to a subject which is so completely fundamental to a proper understanding of the chemistry of the human body is still an unsettled question.

There is no discussion of the chemistry of dyes and stains, a subject which this reviewer believes should have a place in any text of this kind.

Where the object is to curtail the subject matter to a minimum so as to fit the time allotted for the work, this is an excellent text.

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MECHANICS, MOLECULAR PHYSICS, HEAT, AND SOUND. *Robert Andrews Millikan*, Director of the Norman Bridge Laboratory of Physics, California Institute of Technology, *Duane Roller*, Professor of Physics, University of Oklahoma, and *Earnest Charles Watson*, Professor of Physics, California Institute of Technology. Ginn and Company, 15 Ashburton Place, Boston, 1937. xiv + 498 pp. 268 figs. 54 plates. 15 × 23 cm. $4.00.

This text, which is not a revision of Millikan's "Mechanics, Molecular Physics, and Heat," is intended "for the serious student who seeks a thorough training in the sciences or in engineering, and who has already mastered trigonometry, and who has had the equivalent of a good secondary school course in physics". The aim of the authors was a "thorough treatment of fundamental principles, rather than the presentation of a large mass of facts."

The reader gains a remarkably clear and exact picture of some of the history, development, and operation of physics as an experimental science. By means of illustrative plates, biographical references, and quotations from original papers, so inserted as not to interrupt the analytical discussion, a humanistic background is developed for the basic principles of the fields of physics considered. A noteworthy feature is the treatment of subject matter, whereby the details involved in the discussions have been subordinated to a minimum number of fundamental principles which are continually emphasized.

In the body of the text detailed instructions are given for thirty-two experiments under fifteen general topics. By this close correlation of class work with laboratory work the beginner will appreciate and understand the experimental method of attack in scientific investigations. In addition, twenty-two "Optional Laboratory Problems" are outlined.

There are included, also, problems and a question summary for each chapter, a comprehensive list of review problems at the end of the book, an extensive bibliography of physics material, classified as history, biography, original papers, etc., and the usual appendices and instructions for laboratory use.

The subject matter is presented so clearly, concisely, and logically that it should be readily understood by "the serious student." The calculus which is occasionally used need not deter students who are unfamiliar with it.

Instructors of physics should welcome this text as a help in cultivating an appreciative, comprehensive concept of the aim and scope of physics as an experimental science, by humanistic touches that sacrifice nothing of sound, basic physics to make it "interesting" to the student. "There is very little in the text that will have to be unlearned by the student when he goes on in physics."

C. G. EICHLIN

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THE AROMATIC DIAZO-COMPOUNDS AND THEIR TECHNICAL APPLICATION. *K. H. Saunders*, M.A., F.I.C. Longmans, Green & Company, New York City, 1936. xii + 224 pp. 14.5 × 22.5 cm. $4.25.

Every organic chemist will agree that the diazo reaction is one of the most fundamental and interesting in the whole realm of chemistry. Such varied results can be obtained from the reaction; it can be used for producing such a variety of substances of industrial importance that a certain familiarity with its many-sidedness is essential to a chemical education.

The author of this book has made an effort to bring together the facts regarding this reaction in such a way that the student is brought up to date in the field. At the same time a successful effort has been made to keep the discussion within bounds. It is a pleasure to state that the object of the book has been fulfilled admirably and that we now have a text of just the right character covering an immensely important and fascinatingly interesting group of compounds. It is interesting to note that while most reactions carried out in the organic laboratory are paralleled by natural phenomena, the action of nitrous acid on primary amines is entirely artificial; natural azo and diazo compounds being unknown.

Because of the very great importance of diazo compounds in the organic industry, this text should be familiar to every student of chemical engineering, as well as to those specializing in organic chemistry. The student may overlook a number of errors, most of them typographical, but many of them serious in altering the meaning. Rather than list the corrections that should be made your reviewer would refer the student to the excellent review by F. M. Rowe, which appeared in the *Journal of the Society of Dyers and Colourists*, Volume 53, No. 2, page 64, February, 1937.

ROBERT E. ROSE

E. I. DU PONT DE NEMOURS & CO., INC.
TECHNICAL LABORATORY
ORGANIC CHEMICALS DEPARTMENT
WILMINGTON, DELAWARE

THE CHEMICAL WHO'S WHO, VOLUME II. Edited by *William Haynes*. The Haynes & George Company, New Haven, Connecticut, 1937. 543 pp. 14.5 × 23 cm. $6.00.

In two important respects this volume differs from its predecessor published in 1928. These changes are indicated in the change in title from "Who's Who in the Chemical and Drug Industries" to "Chemical Who's Who." The scope of the book has been at once narrowed and deepened.

Many names from the allied, but increasingly distinct, medicinal and cosmetic industries have been dropped. Within the chemical field proper, however, the rather strictly industrial point of view of the first volume has been widened to include technical and educational leaders. Thus, specifically, while the president of an important perfumery manufacturing concern has been omitted, the chemical chiefs of their technical and research staffs have been included.

As always in a work of this kind, selection has been guided both by the position a man holds and by the work he has accomplished. Full professors of chemistry and chemical engineering at the leading colleges and universities, as well as the executive heads of all important chemical concerns, have been automatically included. Bureau chiefs and chief chemists in federal and state service will also be found in the following pages. In commercial and professional fields recognition has been made of outstanding chemical work regardless of title. In the industrial group department and branch office managers, directors of research, superintendents of large plants, and the chief chemists in chemical converting and processing industries have been included. In most instances omissions are due rather to failure to return the questionnaire than to oversight.